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Bulletin of the INTERNATIONAL OCEANOGRAPHIC FOUNDATION

NOVEMBER 1960 Volume 5, No. 6

VOLCANIC ICEBERG? *Flames, steam, smoke and spiralling ice bits erupt as the U. S. Coast Guard conducts thermite demolition tests at Cape Bonavista Bay, Newfoundland. Six incendiary charges, each containing 28 pounds of thermite, were used to make little ones out of this big one, and remove another menace to navigation. (U. S. Coast Guard)*

FRONT COVER. ARCTIC NOCTURNE. *As a seagull wings its solitary way, it seems to symbolize the loneliness of northern seas during the long summer days when the sun sinks only a little lower and then climbs again. This hauntingly beautiful photograph was taken at 1 A.M., on an August morning in 1958. (F. Hamilton Woodcock)*

BACK COVER. ANTARCTIC RECEPTION COMMITTEE. *When scientists and other personnel of "Operation Deepfreeze" arrived at their base they were greeted by this quartet of penguins, curious about a large mystery, the ice breaker* U.S.S. Glacier, *which has invaded their isolated domain. It is in this ice-locked farthest south region that an important phase of the studies of salt water fungi is being conducted. (See "Mysterious Sea Fungi" in this issue) (U. S. Navy)*

SEA FRONTIERS

Bulletin of the INTERNATIONAL OCEANOGRAPHIC FOUNDATION

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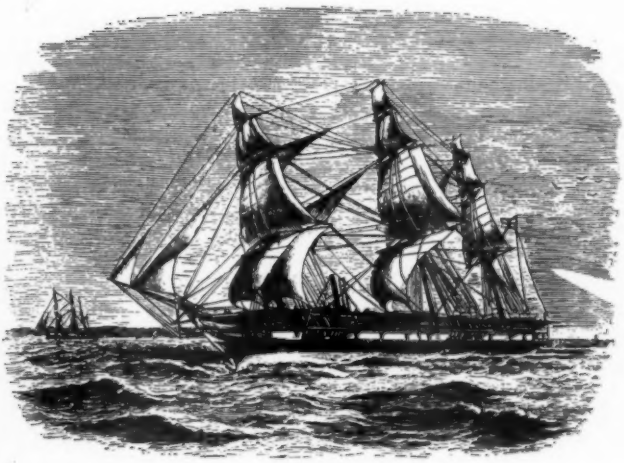

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TROPICAL HEADQUARTERS *for Scandinavian exchange scientists is The Marine Laboratory, University of Miami, on Virginia Key, Miami. Visiting scientists will travel, however, to other tropical marine stations. This aerial view shows the buildings, dock, and part of the fleet of vessels available for research work in nearby tropical waters. (Miami Seaquarium)*

Hands Across The Sea

By MARGARET BIGGERSTAFF

AT THE CONCLUSION of the World Congress of Oceanography, held at the United Nations, New York, August, 1959, some leading scientists from Scandinavian countries decided to take advantage of the opportunity to pay a visit to tropical American seas. There has always been great curiosity in Nordic nations concerning the differences between the marine life of cold northern waters and warm tropical seas.

When The Marine Laboratory of the University of Miami, which is located at the edge of the West Indies, extended an invitation to these Scandinavian scientists to inspect some of the work it is doing in tropical and sub-tropical waters they accepted with alacrity.

Exchange Program Discussed

Enthusiasm of the visitors ran high, not only for what they saw and heard, but also at the alluring prospect of a program of studies and research, whereby scientists might be exchanged on a continuing basis. Informal discussion led to a suggestion that an exchange program in marine biology be set up, and that two scientists be sent to the tropical United States each year from Nordic countries (Norway, Sweden, Denmark and Finland), and two be sent to Scandinavia from the United States, each nominee to have six months' study and fieldwork in these contrasting environments.

It was further proposed that the Nordic Council for Marine Biology be the sponsor from Scandinavia and the International Oceanographic Foundation from the United States.

Committee Set Up

The result of these pleasant talks in Miami was the establishment of a formal committee, empowered to take whatever action was necessary to get the program under way. The Nordic-American Scientific Exchange Committee, as it is called, consists of leading scientists and public figures from each of the four Scandinavian countries and from the United States. Dr. F. G. Walton Smith, Vice President of the Foundation, was appointed Chairman of the Committee and the author the Secretary.

In the year since the inception of the Committee, many letters and much data have been exchanged. Most gratifying responses have come from both diplomatic and business circles of the countries involved, as well as an awakened interest in what oceanography contributes to our everyday lives, and to medicine, industry, national defense, etc.

First Scientist Selected

The first scientist to receive the Fellowship Award from the Scandinavian countries is Dr. Fredrik Beyer, of Blindern, Oslo, Norway. He was chosen unanimously as an outstanding contributor in the field of marine

FIRST SCIENTIST *from Scandinavian countries to receive the Fellowship Award of the Nordic-American Scientific Exchange Committee is Dr. Fredrik Beyer, of Blindern, Oslo, Norway, shown here at the helm of the research vessel of the Institute for Marine Biology, University of Oslo. Dr. Beyer has spent considerable time at British laboratories and has an excellent command of English. (Photo from Dr. Beyer)*

biology, and has already arrived in the United States to begin his six months of research in these new (to him) tropical waters. Like other Fellows who will come from the Scandinavian countries, he will be based at The Marine Laboratory, Miami, but will be free to travel to other tropical marine stations.

Dr. Beyer studied with Professor Johan Ruud, noted Norwegian marine biologist, and has spent considerable time at British laboratories, so he has an excellent command of English, and can avail himself of the large reference library in the Miami Marine Laboratory.

Bottom Net on Sledge

Perhaps Dr. Beyer's most remarkable contribution to oceanic exploration is a deep sea net which slides over the bottom of the ocean on a light sled. With it he has made very successful hauls for bathypelagic organisms inside and outside of Oslofjord, with good catches of smaller fishes, some of them rarely taken by conventional methods.

While the net-and-sledge combination is not an original idea, Dr. Beyer's device has advantages not found in others. It can travel at any level in the water, independent of the bottom. The apparatus also can be towed along rather rough bottom, and in sharp curves, without capsizing. The sledge will not sink into the bottom deposits, no matter how soft they may be. If by chance it catches on some obstacle, the net is automatically closed and secured, and released from the bottom.

New Type Medusa

By means of this new equipment most complete records of Oslofjord deeps have been obtained. One outstanding catch was an entirely unknown type of Medusa (a kind of jelly-fish), which Dr. Beyer described in a special publication in 1958. There is every reason to believe that the application of this technique to tropical waters should reveal new

features of the fauna composition and distribution, and possibly unknown species as well.

The Nordic-American Scientific Exchange program will be officially launched early in 1961, in Miami, with the participation of the Ambassadors of the Scandinavian countries to the United States. The Voice of America will carry the ceremonies, in which high officials of the American educational, business and industrial fields will also take part.

Your Help is Needed

The International Oceanographic Foundation has accepted the responsibility of raising funds for this exchange program, and invites industrial corporations with Scandinavian interests and/or origin to participate by becoming Corporate Members of the Foundation. In appreciation, the Foundation will place their names on a special plaque in the Scandinavian Room of the new Museum Building at The Marine Laboratory, which is now being planned. All persons interested in this program are invited to become members of the I.O.F. Donations are, of course, tax deductible.

MOST REMARKABLE *contribution to oceanic exploration made by Dr. Beyer is a deep sea net which slides over the bottom of the ocean on a light sled. While not an original idea, Dr. Beyer's device has many advantages not found in others. It can travel at any level in the water and if, by chance, it catches on some obstacle, the net is automatically closed and the apparatus released. (Photo from Dr. Beyer)*

The importance of this new exchange program can hardly be overemphasized. Few persons or industries in the world do not benefit directly, or indirectly, from oceanographic research, which is really in its infancy. The oceans, in fact, are "the last open range from which we will be able to amplify future protein food supplies"—which is another way of saying "the survival of mankind."

Fresh Water from Sea for Virgins

The Virgin Islands may soon have a water distillation plant to convert sea water into fresh water. Plans have been approved by the Interior Department to replace the catchment basins and water barge service from Puerto Rico, which cannot meet the needs of St. Thomas, due to recent population and tourist industry growth, and per capita use. Bids have been invited on a plant that would produce 250,000 gallons of fresh water a day. It is designed for expansion to 500,000 gallons a day.

HIGHLY PRAISED *for its pearly inside is the abalone, which can be polished to a beautiful lustre. Dark areas indicate blue-green or turquoise coloring. The holes are for excurrent breathing. (Fleming Photo)*

Sea Ear

By RAYMOND M. GILMORE
San Diego Natural History Museum

A GREAT MOLLUSCAN univalve is the abalone, highly prized for both its exquisite shell and its delectable meat. Close relative of the giant limpet, the abalone looks like an enormous human ear; and, in fact, some call it an "ear shell." Its generic name, *Haliotis,* comes from two Greek words meaning "sea ear."

The sea ear has an oval shell which protects the upper half of its body; the lower half is bare, a muscular "foot" that can either cling tenaciously, or move the animal, sometimes quite rapidly for a mollusk—up to three feet a minute.

As shellfish go, the abalone is big. The largest, the red abalone, *H. ru-*

fescens, attains a maximum length of twelve inches, and may weigh as much as eight pounds as it comes from the water! Most red abalone, however, are eight to nine inches, and weigh about four pounds. Even the smaller species on the California coast grow to six or eight inches, and weigh half to one pound.

It may come as a surprise to some shell collectors and gourmets that abalones of the genus *Haliotis* occur in many parts of the world. Scientists have located them off Africa, in the Mediterranean, and near southern England, as well as in New Zealand and Australian waters. Others occur in the Galapagos, the Marshall Islands of the Pacific, and there is even a rare species in Florida waters.

Small and Very Rare

As for the latter, it might be mentioned that the original specimen of *Haliotis pourtalese,* from the Florida Keys, was destroyed in the great Chicago fire. This rarest of abalones reaches a length of only one-half to one inch, and is found in depths from 65 to 200 fathoms, mostly along the Florida Keys. Probably less than a dozen specimens are known, most of them cast up by the sea.

Only in the north Pacific, along the coasts of California and Oregon, along the east coasts of Asia and Africa, and in the Channel Islands near France does the abalone become large enough to be useful to man, either as a food or for its by-products.

Most Familiar Species

Let us focus attention on the abalones of the Pacific coast of North America, because these are not only the best known, but commercially the most valuable members of the order Docoglossa, class Gastropoda. According to John Fitch, of the California Fisheries Laboratory, the following species occur:

(1) pink or corrugated, (2) red, (3) green, (4) black, (5) threaded or white, (6) flat, or northern green, (7) Japanese or pinto, and (8) white or delicate yellow.

Their scientific names are, in order, *Haliotis corrugata, H. rufescens, H. fulgens, H. cracherodi, H. assimilis, H. wallalensis, H. kamtschatkana,* and *H. sorenseni.*

Fishing License Needed

Look for the abalone only along rocky shores, because it does not inhabit sandy beaches. Abalones favor wave-washed rocks, especially the undersides, and most of them are not exposed to view except at very low tide. Nor may they be collected at will. Abalones are wards of the state, and you must have a fishing license to gather them for their meat or shells. Only those of legal size may be retained.

California has other restrictions, imposed to keep the abalone from going the way of the queen conch in the Florida Keys. You must have a device for measuring the abalone. Legal sizes vary with the species. Also your handiron or "ab-iron," for prying the animal off the rocks, cannot exceed 36 inches in length, which means you cannot use a shovel, although a screw driver is legal. The bag limit is five a day of any one, or any aggregate of, species.

Like certain fish and game, abalone in California can be caught only "in season" — from March 16, through the rest of the year, to January 14 of the following year. During the remaining period, January 15 to March 15, abalone must not be molested in any way. This closed interval was originally thought to be the spawning period, but later it was shown that spawning takes place almost throughout the year, although with greater frequency in the summer months.

As for the abalone's sex life, the gonads, or reproductive glands, are large, turgid, horn-shaped organs partially coiled around the shell just under the mantle, along with the gut. The male gonad is light colored, the female dark and granular.

Abalone Has Sexes!

In the abalone, the sexes are in different individuals. Each is thus either male or female, or dioecious, not monoecious or hermophroditic (both sexes in the same individual), as are many other species of shellfish. Dioecious means literally two houses, one for each sex. There is no difference in size between the sexes.

Abalone eggs are heavy, and stay or roll on the bottom, where they soon become lodged, if not gobbled up by predators. The eggs must be a delicacy for other marine creatures, for the abalone spawns enormous numbers of them to assure the continuation of the species. For instance, the first ovulation of one red abalone, at six years of age, produced an estimated 100,000 eggs. A seven-inch specimen, presumably ten years old, turned out 2½ million. The sea, in such cases, must be milky with spawn, and the mortality tremendous.

Finds Kelp-Holdfast

The lucky survivors hatch within a few days into tiny, globular larvae, which swim freely by means of beating cilia, or hairs. In about three months, they leave the bottom-plankton community, seek out a rough surface, usually a rock, and settle at the base of a kelp-holdfast, or algal stalk, where they can feed.

The young abalone soon secretes a tiny shell, a perfect replication of the adult, even to the tiny, open holes through which the water passes from the gills. One can readily understand how the ancient belief in preformation of the embryo in the exact image of the adult, without unfolding development, could arise.

Catcher Must Be Quick!

The trick of getting a live abalone off the rock is to be quick—quicker than the grip of the abalone. Normally the abalone stands up a bit from the rock, half an inch or so, its foot pressed firmly against the rock, but not yet in the vice-like hold it assumes when frightened or attacked. The tentacles of the mantle curl out from the edge of the shell, groping for algal food and location by touch.

OLD-FASHIONED GEAR *is used by Mexican abalone divers off the San Benito Islands. Here a diver prepares to descend to as deep as 100 feet, where the abalone are as yet largely unharvested. The catch will be hoisted in net baskets. (R. M. Gilmore)*

OUT OF THE DEPTHS *emerges a net basket of abalones, filled by a diver working along the murky bottom, sixty feet below. A part of the city of San Diego, California, is in the background. (Al Allanson)*

But an abalone can come down on the end of a catcher's iron with the sharp edge of its shell at surprising speed. Then you have to force the iron under the foot to break the powerful suction slowly by admittance of water or air. This must be done carefully, or you may break the shell, without dislodging the abalone.

Watch Your Fingers

A word of caution: don't use your fingers to pry one from the rocks, although experts can do it if they are fast enough. Novices may find their fingers caught under the edge, and a severe pinch can result. However, there is no danger of the collector being trapped and drowning when the tide rises, as fiction writers would have you believe. In fact, it is sometimes possible to pry an abalone loose easily, with a quick pull.

Nevertheless, the force of adherance, or attachment, is great. It has been demonstrated that an abalone of six inches can grip, when alarmed, with a force of 400 pounds!

Return Sub-Sizes

If you are successful in flipping the shell off the rock with one quick pry of the ab-iron, identify the species, and, if it is under legal-size, return it

to the rock—foot down. If it is legal size, put it in a sack. The retained abalones will slowly and silently expire out of water. Fresh water will speed the process.

While abalone collecting is restricted in the State of California, for shell collectors, skin divers and commercial fishing interests, it is prohibited for all outsiders in neighboring Baja California, Mexico. Incidentally, the word abalone comes from the Spanish *abulon*.

Principal Species

For identification purposes, let us take a brief look at the principal species of abalone found on the west coast of the United States. Green abalone is actually a blue-green, and then only on the inside of the shell, the beautiful iridescent mother-of-pearl, or nacre. This can be readily seen at the edge of the mantle, when the abalone is in the hand. This species is also termed blue abalone. The outer surface is a dirty, pale brown. It is found from Point Conception, California, south to Magdalena Bay

COMMERCIAL FISHERMEN *must carefully measure all their catches, because legal sizes vary with the species. But they can capture great numbers. For sports fishermen the limit is five a day. Another restriction: hand-irons or "ab-irons," for prying the animals off the rocks, cannot exceed 36 inches in length. This means that sports fishermen cannot use a shovel, although a screw driver is legal. (Al Allanson)*

ABALONES AT HOME. *Tidal coves along the rocky shores of Oregon, California and Baja California (Mexico) are haunts of this molluscan univalve, although abalones are also found in some other parts of the world. Note that a few cling to the under side of the rocks here at San Miguel Island, off southern California. (Al Allanson)*

in Mexico. The minimum legal size is 6¼ inches on the long diameter of the shell.

Mixed with the blue-green abalone in southern California and extending to the northern part of the State where, north of San Francisco, it is the dominant species, is the flat, or northern green abalone. Actually it is reddish-turquoise on the inside and underlip, and is smaller and flatter than the southern green. In southern California divers do not distinguish between the two species, despite the slightly smaller legal limit of six inches for the northern green.

The red abalone, largest of the tribe, shows visible red on the outside, even through the dirt and growth of attached organisms. The mother-of-pearl inside is iridescent pink and green; and the legal size begins at seven inches.

Beautiful Black

Next most common species, the black abalone, is intertidal in most of the cool waters of central California, and in much of the favorable areas of southern California and northern Baja California, Mexico. In some out-of-the-way places, it can be found practically covering the rocks at low tide, where it looks white when dry.

Some abalone fanciers claim it has the most beautiful shell of all. The color is really deep blue-black on the outside after the encrustations have been removed and the surface polished. It gleams pearly on the inside. The shell of the black abalone is smaller and deeper than those of the red and the green. The minimum legal size is five inches.

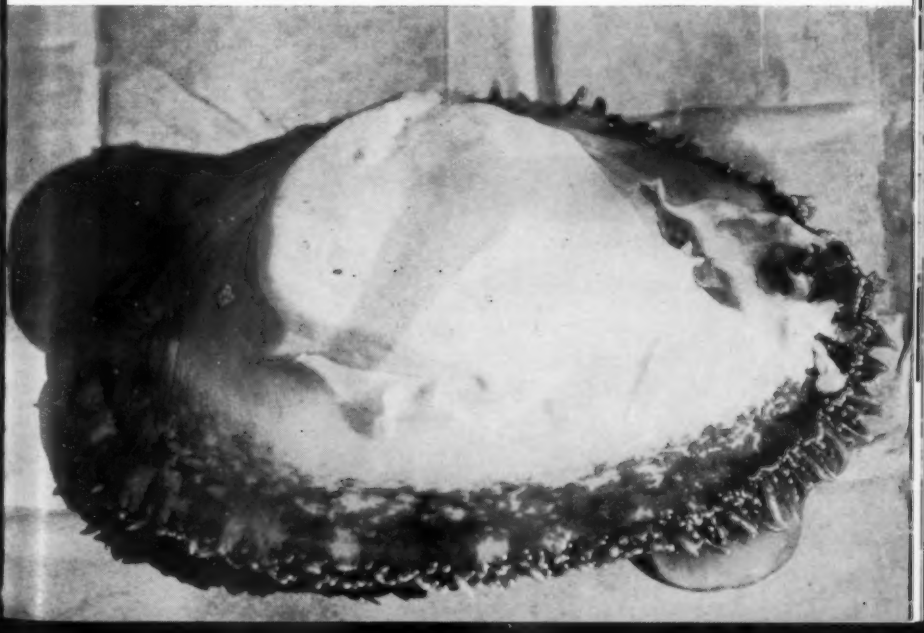
Introduced into Hawaii

The black abalone is apparently more adaptable to varying water temperatures, and, for this reason, was selected for introduction into coastal areas of Oahu, Hawaii, in late 1959. It is too early to determine whether this transplanting is successful.

Collectors still report finds of pink abalone in southern California. They may look like the red abalone, but they are smaller and have conspicuously rough and corrugated shells. This has given them the name also of corrugated abalone. The minimum legal size is six inches.

Those who want to add one of the rare white or yellow abalones to their collections will have to journey to the islands of Santa Catalina and San Clemente, off the southern California coast. This delicate species has a thin shell, and, some say, a very tender meat. The outer surface is dull gray, but the foot is yellowish, and the inner lining of the shell is beautifully pearl-colored. Legal size is six inches.

SHELL COLLECTOR'S PRIZE, *gourmet's delight—the abalone. This prime specimen of a green abalone, freshly caught, lies upside down in its shell. The white flesh of the foot (center) makes a delicious steak while the mantle-trimmings are used for chowder or fishing-bait. During life the mantle secretes the shell. It is fringed with tentacle-like projections, as shown below, which act as sensory organs. (R. M. Gilmore)*



ANOTHER BY-PRODUCT, JEWELRY. *Abalone shells, after being polished on both sides, make striking ornaments, including earrings, brooches and belts. The large shell is an eye-catcher or "conversation piece" for the living room table. (Al Allanson)*

Only professional commercial divers are likely to secure live specimens of the threaded or deep-water abalone, because it lives mostly at depths of 50 to 100 feet, although it has been reported at depths of 10 feet. Empty shells are sometimes cast up on beaches after a storm. The ribs of the shell are bumpy or beaded.

What do abalones eat? Nothing but algae, mostly the small seaweeds that grow abundantly on rocks to the depth of 100 feet, which is about as far as life-giving sunlight will penetrate in these waters. The limit of growing algae marks the limit of living abalone.

The giant kelps, *Macrocystis* and *Nereocystis,* are favorite foods. But the abalone does not climb the stipes nor mount the leaves near the surface. Rather, it waits on the bottom for fragments broken loose by heavy currents or waves. These it seizes with a startling avidity as it senses them at close range, without eyes that can define a sharp image, but only distinguish light from dark!

Few Contaminations

Abalone meat itself is usually white and pure. There is no contamination with the virulent poisons from red-tide organisms in California, as with mussels, which are quarantined for this reason in summer. Some abalones have worm-cysts, but these are not harmful to man, even if taken raw, and cooking kills them. Occasionally abalone flesh is gray, but this does not mean contamination unless localized and very dark.

The flesh of abalone cannot be canned in, nor exported fresh or frozen out of California, if taken within the State. However, mantle-trimmings can be canned for chowder or bait. Fresh frozen meat and canned products from Baja California, since 1959, may be imported to California and then shipped to outside markets. Mexican frozen abalone steaks were a special treat for New York restaurant diners during Lent in 1960.

Japanese abalone is exported to the United States in cans, and is available in chunk form at many grocery stores. Asian abalones are served in many Chinese restaurants throughout the

United States, and are delicious when prepared in small chunks with an exotic sauce.

"Blister Pearls"

The dark pearls in abalones, sometimes called "blister pearls," form on the inner surface by nacre deposited around an irritation, usually a tiny, boring clam, *Pholadidea parva.* Loose, round pearls and big blisters have been found in the gonads — a strange place. In Baja California tourists are sometimes approached by stealthy strangers offering dark pearls "at bargain price." The price should be low, for the abalone pearl has little value, and, except as curiosities, there is no market for them.

In addition to man, the abalone has several other enemies, including a number of fishes and the sea otter. Both abalone and otter live in the murky forests of giant kelp, where the otter apparently has no difficulty in plucking an abalone from the rocks. Bringing it to the surface, the otter, lying on its back and holding the abalone deftly in its paws, chews the entire body out of the shell, which it then casts aside—consummately!

EAGER ANTICIPATION *shows on the faces of two diners about to partake of one of the most celebrated delicacies of the sea —abalone steaks. With salad and French fried potatoes, abalone is a meal in itself and one of the culinary "musts" for every visitor to California. (Boyd, from Reed, Miller and Murphy Agency)*

Along the rugged, almost inaccessible coastline between Monterey and San Simeon the sea otter has survived the slaughter of relatives sought by early fur traders. But now he has the abalone fisherman to deal with. When, in 1956, abalone showed a mysterious slump in abundance, enraged fishermen blamed the sea otter and, although the little animal is rigidly protected by law, the bodies of dead sea otters soon thereafter appeared on the beaches.

More Than Cooking Required

No story of the abalone would be complete, of course, without some mention of its preparation as a food. Unlike most marine creatures, more than mere cooking is required to make it palatable—quite a bit more! Skill, as well as confidence and experience, is required of the chef.

Fresh abalone, in fact, is so confounded tough and rubbery that one wonders how anyone discovered that it could be made fit to eat. It can, but it must be *tenderized*. Unless you perform this duty correctly, your abalone is wasted.

The commonest way to prepare abalone is as a steak, the way it generally will be served in a restaurant. Dig the great, muscular foot out of the shell. Trim off the entrails and frilly mantle. Now shave or wirebrush the dark skin off the lower part of the foot—it is on the bitter side.

Next slice with a sharp knife, *parallel* to the bottom of the foot. This is across the grain. Three-eighths of an inch is a good thickness. Then, pound on a wooden board with a wooden mallet. Pound slowly and gently—easy does it—and suddenly the white flesh will soften and a white juice run. This is it!

Batter with cracker crumbs in egg, and fry quickly in hot, deep fat. Forty-five seconds on each side is enough, because the meat is already tender, and overcooking dries and toughens. Or you can grind the fresh meat in a meat-grinder, and bake it as a loaf. Chowder can also be made from the ground meat, with some clam juice for added flavor. Tasty abalone-burgers can be prepared from the ground meat, mixed with bread and onions in egg batter.

If all this seems to be too much trouble, I give you the recipe of a California pioneer: "Nail the meat on a board, put it out to weather for a month, and then eat the board!"

Secretes Its Own Boat

The argonaut, or paper nautilus, is an octopus-like creature that in legend sails the sea in a shell boat. The "sails" on the arms of the female have glands which secrete calcium carbonate, forming a delicate, pearly-white, fluted shell, which is actually a brood case to hold her eggs. Female argonauts grow up to a foot in length, but males seldom exceed half an inch.

AN ENIGMA OF THE SEA. *The mysterious looking bamboo object held in the hands of Thelma Jutare, graduate assistant at The Marine Laboratory, University of Miami, was washed up on the shore at Palm Beach, Florida. The Editors of* Sea Frontiers *have been asked to identify it, but thus far have been unable to do so. Anyone wish to hazard a guess or opinion? (E. John Long)*

Bamboo What-Is-It?

In November, 1955, and again in June, 1957, *Sea Frontiers* published a photo and question mark about a mysterious metal ball, about 5 inches in diameter. One of them had been picked up on Man Island, near Harbour Island, in the Bahamas, and another was found on the beach at Carmel, California. Thus far no one has come forward with a satisfactory explanation as to the origin and function of the two oddities, nor why anything so similar, yet unknown, should show up at places so widely separated.

Now comes another intriguing beach mystery. In August, 1960, wind and wave drove up on the shore at Palm Beach, Florida, a strange bit of bamboo latticework. Even in its damaged condition it reveals fine craftsmanship, and has intrigued everyone who has seen it. Mrs. Jean Smythe, the finder, has shown it to a number of marine authorities, but none has hazarded more than a guess.

No wires or nails were used in its construction, the cross pieces being tightly fitted into holes in the longer sections. The entire construction is of split bamboo. The holes used in fitting the piece together are round and smooth, indicating they were drilled, rather than cut out.

While most of those who have examined it agree that the construction and craftsmanship are of Oriental origin, guesses as to the purpose of the gimmick range from fish trap, flower or vegetable trellis, or some kind of primitive navigational device. Would any of our readers have any information to send to the Editor?

FIRST OFFSHORE SULPHUR MINE. *The largest steel structure ever erected in the ocean is located at Grand Isle, seven miles off the coast of Louisiana in the Gulf of Mexico. Units shown are: (1) heating plant (center foreground), containing boilers, air compressors, pumps and generators, which supply the "tools" necessary to this kind of mining; (2) living quarters (right center) for housing 120 men, kitchen, cafeteria, first-aid room, and offices; (3) heliport, and (4) at far end, the drilling and production platform. The separate drilling installation (left) sinks wells to relieve the ore body of excess mine water. (Freeport Sulphur Company)*

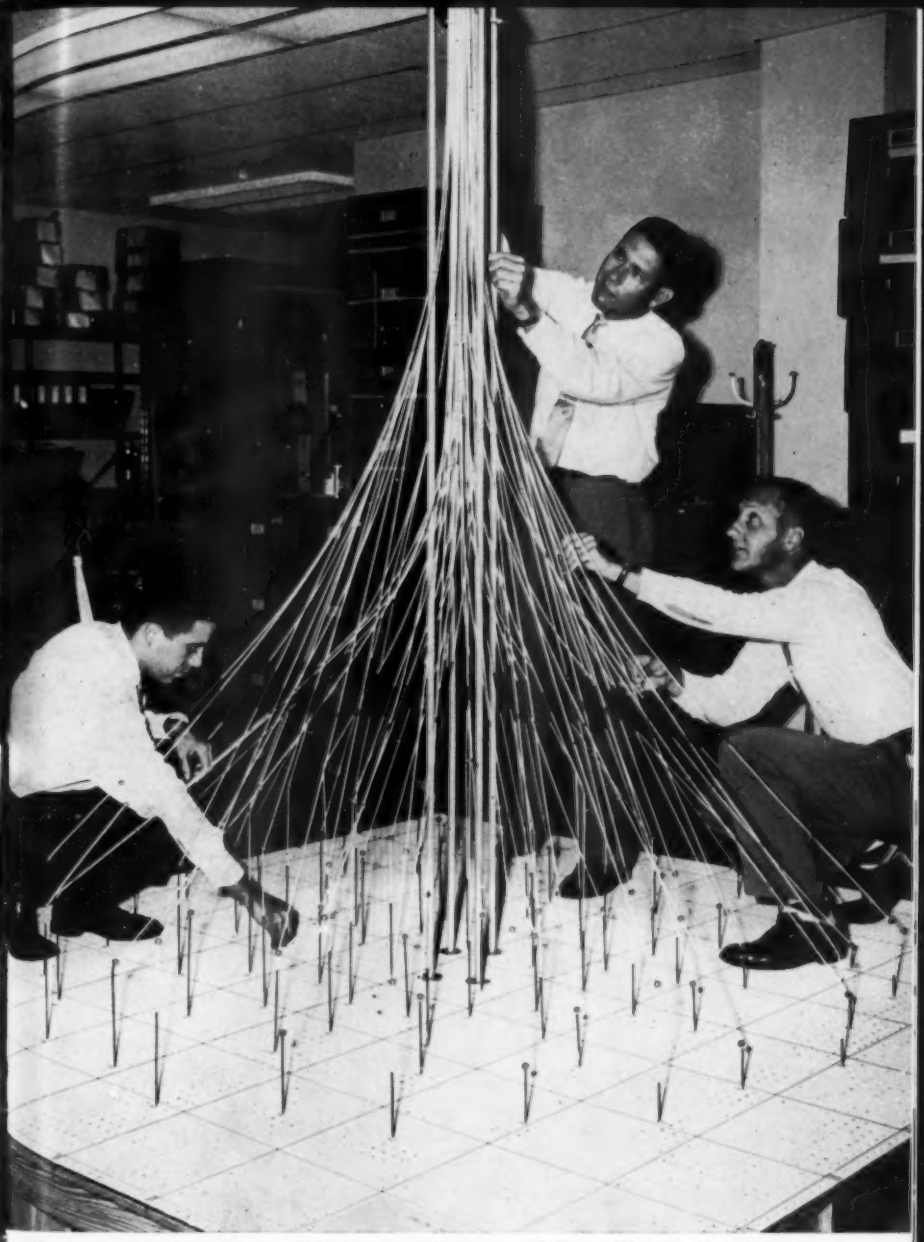
Sulphur Under the Sea

By PHYLLIS PALMER

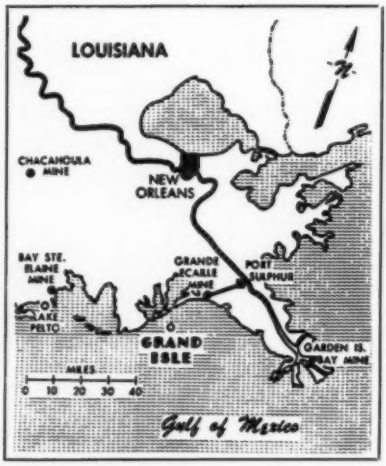
IN THE CONSTANT search for new mineral reserves to keep pace with the rapid depletion of resources found on land, one more industry has turned to mining the depths of the sea. Just as have oil men, sulphur miners now are plumbing the vast open waters of the Gulf of Mexico.

On June 6, 1960, the Freeport Sulphur Company announced that the world's first offshore sulphur mine, known as the Grand Isle project—an enormous steel island rising high above the Gulf — is in operation.

The great sulphur deposit beneath it, the third largest in the United



CURVED LINE IS SHORTEST *distance to underwater sulphur. All wells at Freeport Sulphur Company's Grand Isle offshore mine are drilled directionally. This model shows how wells are bent from the vertical and can therefore reach out laterally as far as 1,250 feet from the surface location. It is thus possible to drill and operate up to 108 wells from one drilling platform! (Freeport Sulphur Company)*



MAP SHOWING LOCATION *of Grand Isle, first under-sea sulphur operation, and land sulphur mines in vicinity. The foundation pilings go through 50 feet of water, and into the floor of the Gulf of Mexico. (National Geographic News Bulletin. Reprinted with permission)*

States, spreads over several hundred acres, and varies from 220 to 425 feet in thickness. It was originally discovered by the Humble Oil Company, but in 1956 Freeport acquired the right to mine it for sulphur.

Located in fifty feet of water, seven miles off the Louisiana coast, Grand Isle is the largest steel structure ever to be erected in the ocean. Actually it stretches, in an S-formation, for a half-mile across the water, and its top deck reaches the height of a six-story building. Equipment on this stilted island includes huge boilers, generators, drills and other facilities for raising sulphur ore from geological formations 2,000 feet below the floor of the Gulf.

Before the discovery of sulphur under the sea, America's supply came from subterranean salt domes along the Louisiana and Texas coasts. These domes, which were themselves originally submerged under water, give vivid evidence of the immense internal forces that have racked the earth.

Pillars of Salt

Basically, they are salt pillars which thrust their way upward eons ago from ancient sedimentary salt beds, perhaps 20,000 feet below the coastal swamps. Some rose to within less than a hundred feet of the surface, at times giving off strong sulphurous fumes; others were more than 2,000 feet down. As oxygen and other elements within these old marine sediments were consumed, their sulphur content remained and was strengthened.

The tops of these pillars are commonly capped with limestone that holds the sulphur ore within its fissures, cracks and seams. In a really productive dome, the sulphur-bearing limestone is sealed in by barren non-sulphur-bearing limestone above, and a layer of equally barren rock below.

All or Nothing

Productive sulphur deposits, however, are rare. Of the 250 salt domes so far discovered in the United States, less than ten per cent contained commercial quantities of sulphur ore. Only twenty have been mined successfully, and, of these, eight are already exhausted! Prospective sulphur-miners should be warned that stakes are high, because there is no

such thing as a small-scale or pilot operation to give prior assurance of profits. In sulphur mining, it is all or nothing at all—much like having to build an entire automobile plant in order to find out whether such a plant can produce automobiles.

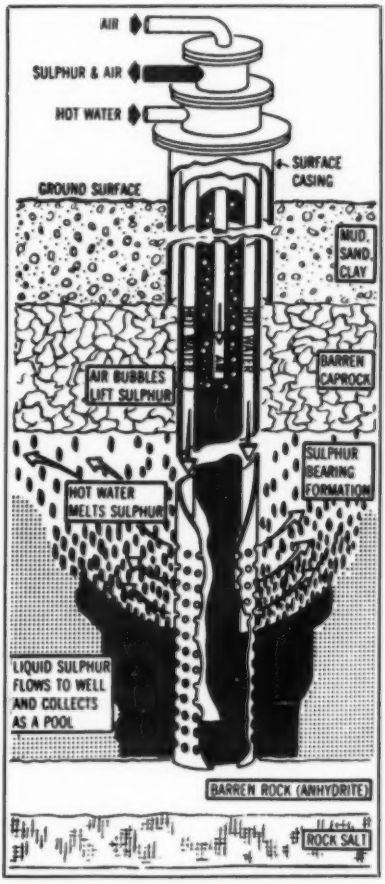
Meanwhile, sulphur consumption has increased three to four per cent each year, with every prospect of the demand continuing. Since virtually every salt dome in Texas and Louisiana has already been probed for sulphur, it is highly unlikely that any more profitable sources will be found on land. Hence the turn to the sea.

It Sounds Easy, But . . .

The Grand Isle venture presented many tough engineering problems. Prefabricated units as heavy as 650 tons had to be barged from shore, and put in place in the exposed waters of the Gulf. Extremes of weather, and the 50-foot water depth of the mine site, compelled innovations in design and construction, while absence of fresh water—a *must* for the Frasch process of sulphur mining—made it necessary to find an alternative.

To meet this, Freeport uses a patented process that heats sea water, rather than fresh water, with a minimum of corrosion and scaling of equipment.

To provide foundations and supports for the plant and other installations, Freeport engineers decided upon a series of towers, connected by 200-foot bridge sections. Largest and heaviest of the installations supported by this basic structure is the water-heating plant, shops and warehouse unit. Four boilers, plus mine-water preheaters, air compressors, and turbo-generators supply the necessary



OPERATION OF A SULPHUR MINE. *Whether a well is drilled on land, or through the bottom of the sea, the basic engineering elements are as shown in this diagram, with hot water melting the sulphur, and air bubbles lifting it. Drilling equipment is similar to that used in the oil industry but the core contains three concentric pipes, within a protective casing. (Freeport Sulphur Company)*

FLOATING "THERMOS BOTTLES." *At some mines, like Freeport's Garden Island Bay property, at the mouth of the Mississippi River, and at Bay Ste. Elaine, about ninety miles west along the Gulf shore, the marshlands will not support the great weight of a sulphur storage vat. As fast as liquid sulphur comes out of the ground, it must be hauled away by a continuous shuttle of heated insulated barges, which deliver the molten mineral to Port Sulphur, on the Mississippi River, below New Orleans. (Freeport Sulphur Company)*

mining tools — hot water and compressed air.

In the Frasch process, discovered by Dr. Herman Frasch in 1894, hot water is forced down to melt the sulphur ore, which can then be aerated with compressed air and brought to the surface. The heating plant, third largest of its kind in the world, can deliver five million gallons of 352°F water per day, and is fueled by thirteen million cubic feet of natural gas daily.

At the opposite end of the island from this plant rises the drilling-production platform. Here, a movable rig drills wells deep into the sulphur deposit. Three pipes are then fitted into the wells. One pipe carries hot water down to the deposit, another provides compressed air to lift the sulphur, and the third brings the liquid sulphur to the surface.

Directional Wells

All of the wells at Grand Isle are being drilled directionally, which means that they are curved from the vertical and are thereby able to reach out almost a quarter of a mile later-

ally from the surface location. The effect is that of an inverted umbrella, and it makes possible the drilling and operating of up to 108 wells from one drilling platform.

Biggest problem of all was getting the sulphur to shore. Use of conventional barges and tugs would have been risky at such an exposed location. The solution was a seven-mile-long, heated pipeline — the world's first underwater sulphur line—buried in the floor of the Gulf, through which the liquid sulphur is pumped to the land base. From there it flows into "thermos bottle" barges, which maintain its liquid state, and finally is towed to storage and shipping facilities at Port Sulphur on the Mississippi River.

Hop a 'Copter to Work

Despite Grand Isle's size and complexity, and its 24-hour-day operations, only a small rotating staff of 175 is required to man the highly automated mine. Crews work 12-hour shifts for five days, and then return to their homes for five days. Helicopters, found to be safer and more dependable than boat transportation over the Gulf, carry the employees to the island heliport and back on a five-day schedule.

Life on this steel island is really more pleasant than might be sup-

HOT SULPHUR IN LIQUID FORM *spews from a pipe into a storage vat, where it soon solidifies. Steamheated pipes have conveyed it from the wells and along the sea bottom to vast rectangular vats which need no permanent walls. The only enclosure required is a narrow strip of aluminum panels at the top rim of the pile. (Freeport Sulphur Company)*

MYSTIC TEMPLE RITES *employed sulphur as far back as 2,000 B.C. Priests used the ethereal blue flame and pungent odor of the burning sulphur during temple sacrifices and purification rites. From this practice, the concept of hell as fire and brimstone (early name for sulphur) may well have arisen. (Freeport Sulphur Company)*

posed, for the air-conditioned dormitory aboard the structure includes sixty double bedrooms, thirty baths, television rooms and recreational areas, as well as kitchen, cafeteria, first-aid room with medical officer, and business offices.

Safety Factor

Since the Grand Isle mine is located where line squalls cause short-lived winds of fifty to ninety miles per hour, and where several hurricanes have passed in the last seventy years, the safety of the island and its inhabitants was a major factor in its structural design.

Consulting meteorologists predicted that winds of 120 miles per hour will occur at the mine site at an average frequency of once each 100 years, and sustained winds of 100 miles per hour will occur each ten years. Consequently, special weather bulletins are constantly issued to the sea mine. In the event of a severe tropical storm, operations can be closed down, and personnel evacuated in ample time.

A unique hazard encountered at any Frasch mine is "subsidence." When enough sulphur has been removed, the rock is weakened sufficiently to cause it to collapse and, since the overlying sediments offer little resistance, the ocean bottom ultimately subsides. Eventually at Grand Isle an elliptically-shaped subsidence basin will spread beneath the structures. Living quarters are expected to settle five feet, and the heating plant three feet. The production or drilling platforms, however, are not permanent structures. They will be salvaged and reconstructed at their original elevations.

Once Known as "Brimstone"

What of the end product itself? While it is one of the most essential elements that man has put to work for himself, sulphur seldom gets credit for its talents. Known in days past as "brimstone," it gained dubious distinction as being the chief fuel of hell, and the awesome images evoked of hellfire and brimstone by ancient temple priests did little to increase its popularity.

Primitive cavemen are said to have eaten sulphur in the springtime to cleanse their blood; the precedent perhaps for sulphur and molasses tonic that was, until recently, the bane of small boys and girls. Early in his-

tory, however, Egyptian artists found sulphur to be an efficient bleaching agent for cotton and linen, and used various sulphur compounds in their color work. The Chinese, during the time of Confucius, invented gunpowder, of which sulphur is a necessary ingredient.

Then Came Sulphuric Acid

Although the first commercial sulphur was produced in Sicily as early as the fifteenth century, it was not until 1735, when a process was developed for the manufacture of sulphuric acid, that the world began to scramble for this now indispensable element.

Today sulphur is a part of practically everything we use. Each person in the United States consumes about seventy-five pounds of it a year, without ever seeing it, just as he never sees the coal contained in a piece of rayon. Four-fifths of all sulphur is made into one of the chemist's cheapest and most valuable tools — sulphuric acid. The acid in turn is used to produce detergents, feed additives, resins, antifreeze, paper, rubber, sulfa drugs, and a host of other products. On the farm, sulphur becomes an ingredient of fertilizer and pesticides; in petroleum refining it is the workhorse which helps to purify gasoline, kerosene and lubricating oils.

CAVEMEN ATE SULPHUR *in the springtime, reputedly to cleanse their blood—a custom which, as sulphur-and-molasses, was until recently the bane of small boys! Modern medical authorities give some praise to the yellow mineral as a source of laxatives and diaphoretics, and in ointments for the skin. (Freeport Sulphur Company)*

Yes, sulphur may have had a shady past, but it has a glowing present, and a most promising future. When land resources of sulphur finally play out, as they will, man must turn to ventures such as Grand Isle, one of the bolder attempts to wrest minerals from the sea. The growth of research in oceanography and submarine geophysics will set the pace for this.

Octopus, Shy Variety

The Mediterranean octopus, unlike the fierce man-killing monster of fiction, is actually a small creature, shy as a mouse, prized for its edible flesh and as bait among residents bordering this great inland sea.

TURNING BACK THE PAGES *of maritime history. In August, 1960, a cache of old ship tools was uncovered on the site of a former British Royal Dockyard at Port Royal, Jamaica. Admiring this early eighteenth Century archeological treasure are (left to right) Sir Anthony Jenkinson, of Morgan's Harbour Beach Club, where the tools were found; Don Pinn, engineer in charge of construction at the club; and W. Adolphe Roberts, Jamaican historian. (Jamaica Tourist Board)*

AERIAL VIEW OF PORT ROYAL, *wealthiest and wickedest city of the New World in the days when it was the haunt of buccaneers. Virtually destroyed by earthquake in 1692, all that remains of Henry Morgan's town is a quiet fishing village, fifteen miles from Kingston, the Jamaica capital. Site of the former naval dockyard, where ancient implements of the shipwright's craft were recently uncovered, is indicated by the arrow, left center. (Jamaica Tourist Board)*

Historic Cache of Caulking Tools

One of the most unusual historical finds in relation to the sea was made recently in Jamaica when workmen uncovered a sizeable cache of caulking tools dating back to the early 1700's. Among the artifacts dug up were heavy mallets, scrapers, spikes, chisels, and other marine hardware once used to remove barnacles, to caulk seams, and otherwise make wooden ships seaworthy again after many months in tropical waters.

In the excavation, too, were stores of pitch and oakum, and lengths of planking, some riddled with teredo, the dreaded worm which was and still is the bane of wooden ships and piling. Prize find was an old metal spearhead, believed to be more than 300 years old.

The discovery was made at Morgan's Harbour, not far from Port Royal, now a sleepy fishing village but, before it was destroyed by an earthquake in 1693, the headquarters of swashbuckling buccaneers and probably the wickedest city in the New World. In 1959, Port Royal was the scene of intensive marine archeological work by the National Geographic-Smithsonian-Link expedition. (*Sea Frontiers,* August, 1959, Vol. 5, No. 3.)

Mysterious Sea Fungi

By ERNEST S. REYNOLDS
The Marine Laboratory, University of Miami

REAR ADMIRAL George J. Dufek, U.S.N., has a well-based vision of Antarctica as "a tourist paradise," and of regular sea and air traffic to this remote frozen land! As commander of the U.S. Naval Support Force in Antarctica during the International Geophysical Year, he has, perhaps, perception denied to most of us, but already it is possible to visit Antarctica, at least for scientific studies.

One such Antarctica study is being developed by The Marine Laboratory of the University of Miami, and is concerned with an unusual subject, namely seagoing fungi. For several years the question of what kinds of fungi live in the sea, and where, has been investigated at this laboratory.

Why the Interest in Fungi?

What is there about these seagoing fungi to arouse the interest of scientists? The answer comes from two directions. They belong to a group which, until recently, was unknown. It is important therefore to learn what makes it possible for them to survive and grow under conditions previously considered unfavorable. It is possible also that new or only slightly understood principles may be discovered, thus extending our knowledge of biology itself.

The ability of any living creature to grow on wood submerged in sea water involves interesting questions in enzymology, the study of the chemical substances which carry on the life processes of all living organisms. Salt water is a very different living place from the atmospheric conditions in which most other fungi live. Oxygen, which is so universally necessary for most living organisms, is available to these organisms as dissolved in the sea water, and the various food elements and foods needed by them are available in minute quantities, also dissolved in sea water.

The second reason involves the fact that fungi can attack and alter such materials as wood and rope. All organisms, of course, influence one another in a variety of ways, and oceanic organisms are no exception. There are many kinds of plants and animals which live on and in wood more or less immersed in the ocean, and these fungi are among the first that attack and help to destroy wood. Since wood is, in many ways, a very desirable material to use in many constructional ways, the study of fungoid destruction is of prime importance.

Do They Help Wood Borers?

Wood borers are especially important in the final destruction of wood in the sea. Recent investigations, however, indicate that they may not be the first to attack newly-immersed wood. If wood is first attacked by microorganisms, including fungi, it

HAZARDS OF BARRIER RESEARCH. *The tiny black dot (arrow) is IGY Deputy Chief Scientist Albert P. Crary, of Canton, N.Y. When a section of the Antarctic barrier broke off while he was working along the edge, he miraculously landed on the ice floe below, unharmed. He was rescued finally by helicopter. (U. S. Navy)*

may provide a better source of food for the wood borers than the fresh wood itself. Thus the stimulation of borer attack by these advance guard organisms may be an important element in the destruction of wood under oceanic conditions.

There is some evidence to support this idea of the relationship of salt water fungi to the borer population. The same types of amino acids, which are important items in the food cycle of at least one type of borer, have been reported to be present in the mycelium or body of the salt water fungi. Moreover borers thrive on this mycelium.

Fungus and Sea Food

A practical aspect of oceanographic study is how to make the best use of the food supplies produced in the oceans. Much basic information concerning the early stages in the food cycle is still lacking, since the relationships of the microfauna and microflora to the entire process of productivity are largely matters of con-

jecture. We think of fish and shell fish as the foods available from the sea. Actually the basic materials from which these edible animals obtain their food, include, as one of the lower rungs of the food ladder of the sea, the microscopic organisms studied by the microbiologist.

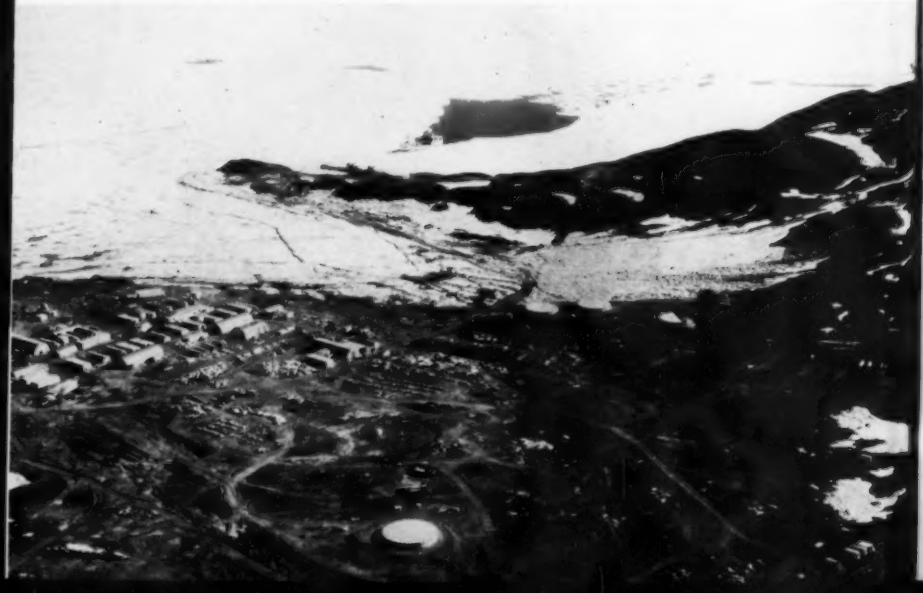
Perhaps as important are the very numerous chemical compounds released to the water in the process of the disintegration of the organic bodies, brought about by these minute organisms. Among these compounds are many, which, although in small concentration in the water, are nevertheless highly important in the building up of the food chain. A factor often forgotten in our worship of the large and the numerous is that in the sea these substances, although in small concentration, are essentially in constant supply, because they are carried to the organism by the renewal of the water surrounding it.

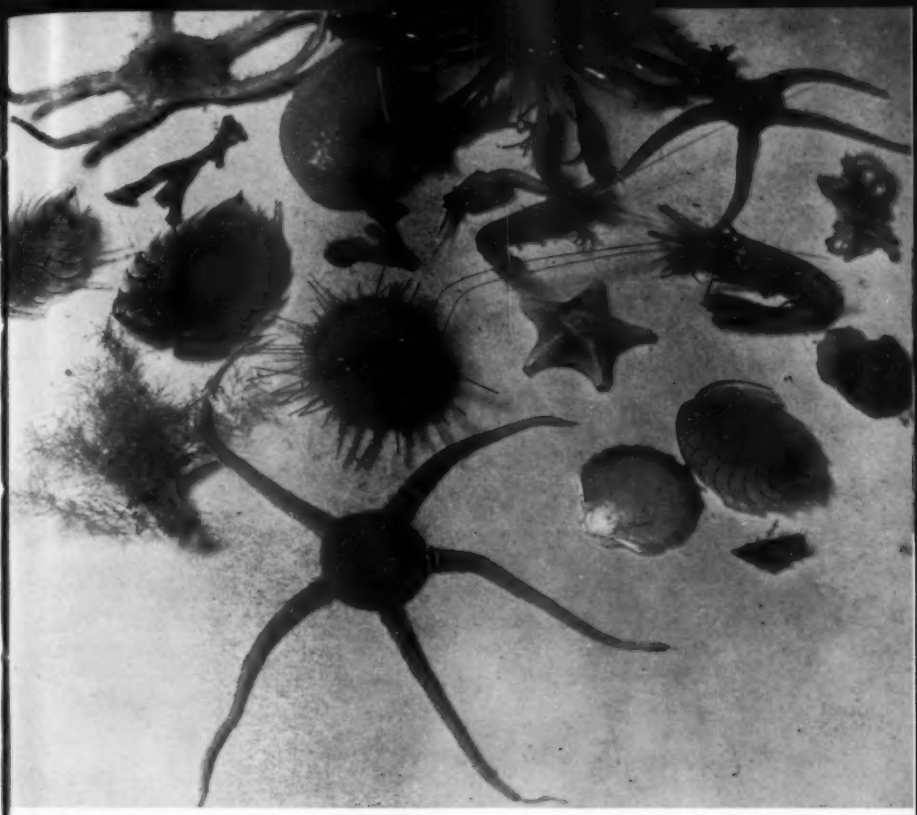
Why Fungi Are Different

The study of fungi which attack wood and other substances immersed in ocean water is part of the general phase of botany called Mycology. This is the science dealing with those odd plants which include yeasts and molds—plants that are not green. Green plants manufacture, with the aid of sunlight, the food on which they live and which, in turn, become the food of animals, including man.

Fungi, on the other hand, do not have the green leaf material called chlorophyll. As a result they are mostly dependent, like animals, on food formed by other plants and ani-

ANTARCTIC BOOMTOWN. *Largest city on the southernmost continent is Naval Air Facility, McMurdo Sound, on the Ross Sea. In addition to scientific laboratories and living quarters, the NAF has warehouses, machine shops, and fuel storage tanks. Ice breakers (top center) keep a channel open to the Antarctic Sea part of the year. (U. S. Navy)*





SUBMARINE RESIDENTS *of Antarctica. When a trawl was lowered from the U.S.S.* Staten Island *to the bottom of the Weddell Sea at 164 fathoms (984 feet), it came up with this strange cargo. Included in the photograph are: brittle stars, starfish, shrimp, crinoid or sea lily, heart urchin, pecten or scallop, bryozans and isopods. (U.S. Navy)*

mals. Many of them live on living plants as parasites, often causing serious injury and death, such as the potato blight and other well-known plant diseases.

Scavenger Fungi

Many fungi help to destroy and free the earth from the dead bodies of plants and animals, and in so doing obtain their food as saprophytes. It is to the latter type that these particular salt water plants belong. A world-wide immersion of wood test-panels was started at Miami a few years ago to gain accurate knowledge of the principal kinds and general distribution of these destructive marine micro-organisms.

With the active cooperation of Dr. Samuel P. Meyers, a considerable number of areas have already been partially explored in this manner, including Alaskan and other high northern regions, under sponsorship of the Office of Naval Research.

A new step in this method of exploration has now been undertaken—the immersion of panels in the Antarctic as part of the program of "Deep Freeze 60." Dr. Donald E. Wohlschlag, director of the new $82,000 biological laboratory at the Naval Air Facility at McMurdo, Antarctica, arranged to have the materials go by air via New Zealand, and the panels are being immersed for a summer period (our winter) and, if feasible, later during the long winter season.

In addition to extension of the exploration for salt water fungi, it is altogether possible that this project will add some otherwise unknown organisms to the list of plants to be found in the Antarctic. This list so far has been limited to lichens and a few species of algae and mosses. Since the experimental panels will be returned to the United States for scientific study, it might be said that the scientists working on the project have made a trip by proxy to the Antarctic for scientific investigation.

Two General Objectives

In the research on these organisms there have been two general objectives concerning their occurrence in marine localities.

Just to discover the various kinds of fungi which survive in the ocean waters, and under favorable circumstances can attack wood, is the first. Thus the opportunity afforded through the arrangement with Deep Freeze 60 extends our research to the new and unique area of the Antarctic.

A second objective is to learn what kinds of fungi are present under various oceanic conditions. In warm, subtropical waters, such as around Miami, there are certain types which can readily be obtained on wood panels, acting as traps. In the northern sub-Arctic areas other types are dominant, and between these two zones a mixture of types has been collected.

During a portion of the cold, northern winter, wood panels became infested with some of these fungi, although they were not visible in the wood when taken from the water. Yet, when these panels are returned to the laboratory and incubated at a warmer temperature, the hidden infestations develop their normal, recognizable characteristics. This latent attack has not been noted in the semi-tropical regions.

Any Similarity to Arctic Fungi?

Now we want to know whether the northern kinds can also be found on panels immersed in the southernmost ocean waters of the Antarctic, and whether other unknown species are present.

The question arises, also, as to the different kinds in different localities. Of course an off-hand answer would be that they are "adapted" to these regions. But the really significant question is, "how did they get that way?" Was it due to the different types evolving in these different localities from an earlier, more generally distributed basic type? Or were there originally several or many widely spread kinds which, due to selective processes, gradually became restricted to the areas where they are now found? Or were other conditions responsible for their present status?

CLOSE-UP OF THE REPRODUCTIVE *bodies, or ascocarps, of a salt water fungus growing on a piece of wood in pure culture. Laboratory technicians have succeeded in forcing growth of these rare organisms which have only recently come under the scrutiny of science. (Marine Laboratory, University of Miami)*

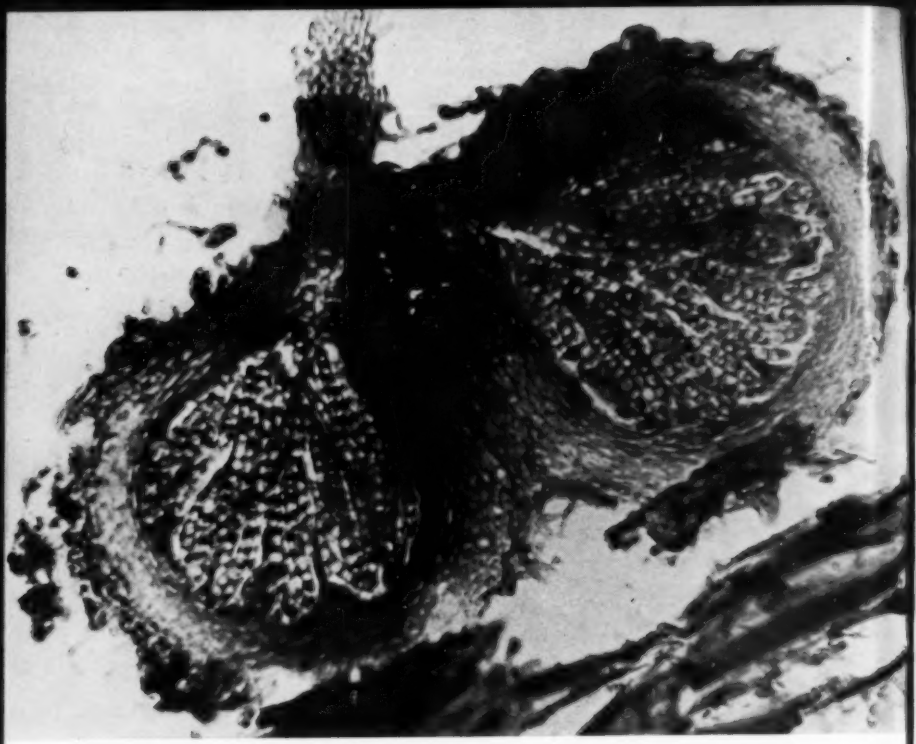
A closely allied problem of evolution is the actual origin of these fungi as salt water forms. Were fungus-like organisms a part of the original population of the salt sea, and have these fungi and their ancestors always been salt water inhabitants? Or were they evolved on land from other plant types and later moved to the oceans?

All such theoretical questions depend for answers not only on a knowledge of the present distribution of fungi, but also on our knowledge of their actual physiological make-up. The latter includes both a study of various individuals and also of the comparative physiology of several kinds, and of similar types among the fungi which attack plant material in land locations, such as wood rots, the mushrooms and toadstools, and the mold fungi.

Fungus Produces Sugars

Of all the fungoid problems, none are more fascinating and basic than the early stages of their attack. Our studies show that these fungi produce chemical substances, known as enzymes, which attack an important portion of the wood substance known as cellulose. As a result of this action, sugars are produced which can constitute a portion of the food they obtain from the wood.

When, however, the first cell of a fungus, known as the spore, becomes attached to a wood surface and it begins to grow, where does the nourishment come from? A minute amount is already in the spore, but not enough to establish the plant on the wood. Even though the wood is dry and clean when it is put into the sea water, it immediately begins to be changed in various ways, due to the action of the water on the wood.



PRIME TARGET FOR *scientists studying salt water fungi. This magnified longitudinal section of the reproductive bodies of a typical salt water fungus shows the numerous spores as small globular objects in the elongated spore sacs. (Marine Laboratory, University of Miami)*

Chemical substances, some of them of food value to the developing fungus, become dissolved and thus available.

Further slow chemical and physical changes occur as the wood absorbs the water. It is possible also that very soon bacterial and other minute organisms arrive and become an active part of the newly developing community on the wood surface. These various changes in the wood and its surface inhabitants influence the development of the fungi and they in turn affect the others.

Mystery Enzymes

Then, a bit later, as the first threads, or hyphae, of the fungus enter the wood, these very active young cells produce enzymes of various kinds, with many of which we are not yet acquainted. How do these attack the wood, resulting in the weakening of its structure and making available other food substances?

We have found, for instance, that wood stimulates these fungi to produce their reproductive structures, whereas a strong growth of fungus may occur on many types of nutritional substances without the production of these structures. All of these

activities are puzzling problems which need to be investigated in order to answer the questions raised by the establishment of fungi on wood in sea water.

Yachtsmen Please Note

It has been known for a long time that the strength of wood is largely due to its ligno-cellulose constituent. Likewise, earlier study shows that certain chemical and biological actions cause deterioration and loss of strength by attacking this substance. Hence we must determine if wood loses strength when attacked by these fungi under saline conditions, even when serious destruction is not visible.

Although it would be very difficult to measure directly such a loss of strength, we have measured serious loss of strength by Manila cordage in natural sea water pure cultures of these fungi. Since also the chief reason for the strength of this material is its ligno-cellulose component, it has been demonstrated that this substance, common to both materials, can be greatly weakened by the growth of these sea water fungi.

HOW MUCH STRENGTH *does salt water fungus remove from the lignin-cellulose material in abaca, or "manila hemp"? Scientists hope to get an answer from these bits of cord soaking in a culture medium of sea water, glucose and yeast extract. (Marine Laboratory, University of Miami)*

Rugged Research Ship

An unusually well-built 38 foot boat has been added to the facilities of the Arctic Research Laboratory of the University of Alaska. Designed for studies of the Arctic Ocean, the vessel has rugged construction seldom found in such small research craft. The keel is gumwood, built to withstand dragging over rocks. Windows and port holes are plate glass. The boat is sheathed in ⅝ inch ironbark, with stainless steel in the bow. "Home port" will be Barrow, Alaska, where the vessel will be pulled up on the beach for the nine months of winter when the seas around Port Barrow are frozen over.

In addition to sonarscope and ship-to-shore radio, equipment includes 12,000 feet of 5/32 inch cable, attached to a hydraulic winch. Berths are provided for four persons.

POINT OF THE JAVELIN. *This close-up of the head of a 52-inch houndfish, a member of the needlefish family, shows its jaws nearly closed. The teeth, which are green, fit closely into grooves or notches in opposing jaws. Despite its unappetizing appearance, and green bones, the houndfish is good eating. (John E. Randall)*

The Living Javelin

By JOHN E. RANDALL
The Marine Laboratory, University of Miami

ON OCTOBER 19, 1959, an article appeared in the *Miami Herald* beneath the heading, "Barracuda Slashes Man's Face," which contained some puzzling information. The man, Clyde Mitchell of Homestead, Florida, was struck by the fish at night after he jumped from his boat into chest-deep water in Biscayne Bay to repair an outboard motor. He said the fish may have been attracted by a boat light which reflected on his face. The suggestion that it might be a barracuda provides the puzzle.

Barracuda, a much maligned fish, is not known to feed at night, nor is it prone to leap from the water to attack an object in the air. Although on rare occasions the great barracuda has bitten man, in nearly every instance this has occurred in turbid or splashing water, when a human limb might be mistaken for a fish, or when a barracuda has been provoked by spearing.

Houndfish, not Barracuda

There is one apparently harmless fish, however, in tropical Western Atlantic waters which is capable of seriously injuring or killing a man by leaping out of the water when attracted, or perhaps confused, by a light at night. This is the houndfish, *Strongylura raphidoma*, one of the

needlefishes. In the West Indies it is sometimes called a gar or garfish, an improper appellation, for true gars are American freshwater fishes.

Mr. Mitchell was contacted, and he stated that he thought the fish which had struck him might have been a houndfish. Other persons had told him it must have been a barracuda, so he had acquiesced. A companion in the boat had seen the three-foot or longer fish skipping on the water toward Mitchell like a silvery streak. The habit of skipping on the surface is not characteristic of barracudas, but is for the synentognath fishes (needlefishes, halfbeaks, and flyingfishes).

The wound, which was in the neck near the chin, provided the best evidence to exonerate the barracuda and implicate the houndfish. It was only one inch long and was so deep that the surgeon attending Mitchell never found the bottom (fearing to probe all the way because of possible damage to vital blood vessels or nerves).

It is difficult to see how a barracuda could make a single wound. Once a barracuda's jaws are open and an object is struck, multiple gashes result from its long sharp teeth. The fish hit Mitchell solidly, and he had to "flip it away" from him; thus one cannot assume a glancing slash by a single tooth. Furthermore, a slash by a single tooth would probably result in a long, relatively shallow cut and not a short, deep wound.

Other Needlefish Incidents

Mr. Mitchell's unfortunate experience is not the only one in Florida waters. Two such incidents have occurred at Miami Beach, one prior to 1936, when a speedboat frightened a houndfish which leaped toward shore and pierced the neck of a man who was standing in the water. A lifeguard had the presence of mind to stick a thumb in the wound on each side of the neck to stem the flow of blood, and the man survived.

Lorelei Sullivan, age twenty, was hit on the left side of the nose near the corner of her eye by a needlefish on May 2, 1953. She was admitted to Mount Sinai Hospital, in Miami Beach, where a 3 by 14 millimeter piece of the fish's beak was successfully removed and the patient discharged.

Leg Pinned to Boat!

About six years ago Captain William B. Gray, curator of the Miami Seaquarium, was collecting marine animals in the Florida Keys at night. He was wading in knee-deep water and dragging a skiff with a light on its bow. A school of large houndfish was startled and began dashing around him. One unusually large one was seen to follow a semicircular path and head toward him. Its beak pierced his right calf just behind the shin bone and momentarily pinned his leg to the side of the boat before it wriggled free and swam away. He still has the scar from this foray.

Later he was the unlucky recipient of an even greater leg wound from the jaws of a bull shark, which resisted efforts to capture it in a seine. Captain Gray reports on these and other experiences in his exciting new book, *Creatures of the Sea.*

"Attacks" by needlefishes are by no means restricted to Florida waters, but are known from tropic seas elsewhere in the world. *Pacific Islands Monthly,* of June, 1958, reported the killing of a Papuan native fisherman by a " 'long tom'—a sort of king-sized garfish with a long sword-like beak." The fish "leapt from the water and punctured the jugular vein."

Who is Harpooning Whom?

An article on harpooning fishes in *Collier's* of January, 1948, reported the death of at least two men from the *agujón,* and discussed the fishing for this needlefish in the vicinity of Acapulco, Mexico. Fishermen take the *agujón* at night with trident spears from dugout canoes, while using torches. From the reference to scars on the fishermen encountering this needlefish, it is evident that this is a hazardous occupation. Not infrequently harpooners and fish exchange roles.

In Tahiti the story of a man who was killed when impaled in the abdomen by a needlefish was related to the author. An interesting superstition still persists among Tahitians with respect to this fish, which they call the *aavere.* If a man has had an argument with his wife, then he should refrain from fishing for the *aavere,* because on that night the *aavere* will strike him.

Not Publicized Enough

Fatalities and injuries from needlefishes have received very little literary attention. In a recent book on dangerous marine organisms the needlefish menace is not even mentioned. Shark and barracuda incidents, in contrast, are today much publicized.

An important distinction should be made between injuries inflicted by needlefishes and those by sharks and barracudas. The latter have directed themselves purposely to man (although not always with full awareness of the nature of the prey) and have bitten with their well-equipped jaws. The needlefish encounters appear to be entirely accidental and involve a ramming of victims by the elongate jaws which are sword-like when closed. Most injuries resulting from needlefishes have occurred at night.

Startled by Lights

C. M. Breder, Jr., of the American Museum of Natural History, discussed the habits of needlefishes in a paper from the Old Tortugas Laboratory, published in 1932. Among the aspects considered was the effect of light on needlefishes at night. Although he noted that two houndfish jumped clear over his skiff and one landed in his lap while rowing at night, he expressed the opinion that these fish do not normally rush headlong toward a light source in air. He stated that the houndfish congregates inshore at night, as scattered individuals and in schools, presumably for the purpose of feeding.

When the beam of a bright flashlight was directed out over the surface, with no fish in sight, a dozen or more would at times suddenly leave the water in violent splashing jumps. Although the jumping occurred in almost every direction, most of the leaps were directed at approximately

right angles to the beam. Successive leaps of what seemed to be a single fish usually resulted in its working itself away from the light. It is obvious, however, that only an occasional wild leap in the direction of the boat is needed to produce a disastrous result. This would seem more likely to occur when a school of needlefish, rather than a single individual, is startled by the light.

While it is true that cases of needlefishes hitting man are not common, it is also true that a safety measure is easily attained in the form of a shield. A person who is fond of night fishing inshore with a light in a tropical or sub-tropical area would be wise to erect a stout shield between himself and the light source and probably on the sides as well. Such a shield could also serve as a reflector.

Green Bones Repel

Not all that can be written about needlefishes is so grim. For one thing, they are edible. In a book on the fishes of Puerto Rico, published in 1907, Evermann and Marsh wrote in reference to needlefishes: "Most of them are good food fishes but the green color of the bones of the larger species often causes them to be avoided, for no good reason." They apparently never cause ciguatera (fish poisoning).

Needlefishes live at or near the surface and are protectively colored for this mode of life, being blue or green on the back and shading to silvery white on the sides and abdomen. They feed on small fishes and not infrequently are caught by trolling lures.

A KINGSIZE HOUNDFISH. *The author's son points to a 52-inch specimen caught in the Virgin Islands. The big fish, which weighed ten pounds, nine ounces, had a two pound ovary containing more than 25,000 ripe eggs. (John E. Randall)*

INVITING TROUBLE — *if big houndfish are near! Exposed lights sometimes induce these "living javelins" to leap at high speed from the water and, with their long sharp bills, injure anyone in their path. A simple wooden or metal shield should be used to protect fishermen from this hazard to night fishing in tropical or subtropical waters. (Helen A. Randall)*

In turn, they are preyed upon by sea birds and such fishes as barracudas and jacks. Off the wharf at Fort Jefferson, Tortugas, E. W. Gudger watched a group of needlefish being chased by a school of jacks, which were apparently not large enough to engulf the entire needlefish, but snapped at their tail regions. Every one of the needlefish lost its tail and all were swimming feebly with their stumps after the jacks departed.

Certain needlefishes have been observed repeatedly leaping over small floating sticks, as if at play. Breder reported a single fish jumping back and forth over a piece of straw as many as a dozen times. He is dubious, however, that such fish are playing. He noted that some part of the fish was usually rubbed against the floating object as it leaped and suggested that this activity may represent an attempt to dislodge skin parasites. Since they live at the surface, needlefishes do not have recourse to scratching a source of irritation on rock or sand as do bottom-dwelling fishes.

Needlefishes are unique in their possession of large eggs. Those of the 10-pound 9-ounce houndfish measured 4.1 to 4.6 millimeters (about 1/6 of an inch) in diameter. Eggs of most marine fishes are less than a quarter of this in size.

Numerous tiny threads can be teased with dissecting needles from the outer, tough covering of the houndfish eggs. These threads probably serve to attach the eggs to floating objects. The eggs have no oil droplets to keep them afloat. A freshly-eaten mass of needlefish eggs was found in the stomach of a 5½-pound dog snapper *(Lutjanus jocu)* in the Virgin Islands.

This mass sank slowly when placed in sea water.

Certain young needlefishes, an inch or so in length, are dark colored and float motionless and straight at the surface. In this pose they resemble floating twigs. Juveniles about five inches long of a needlefish *(Strongylura timicu)* in the Virgin Islands were observed imitating floating pieces of manatee grass *(Cymodocea)*. The fish were straw-colored like many of the grass fragments and frequently held their bodies in an arc as they floated, seemingly inert, beside curved pieces of the grass.

When one looks at these helpless little needlefish, trying so hard to conceal themselves, it is difficult to conceive that they will grow into formidable adult fish capable of killing a man.

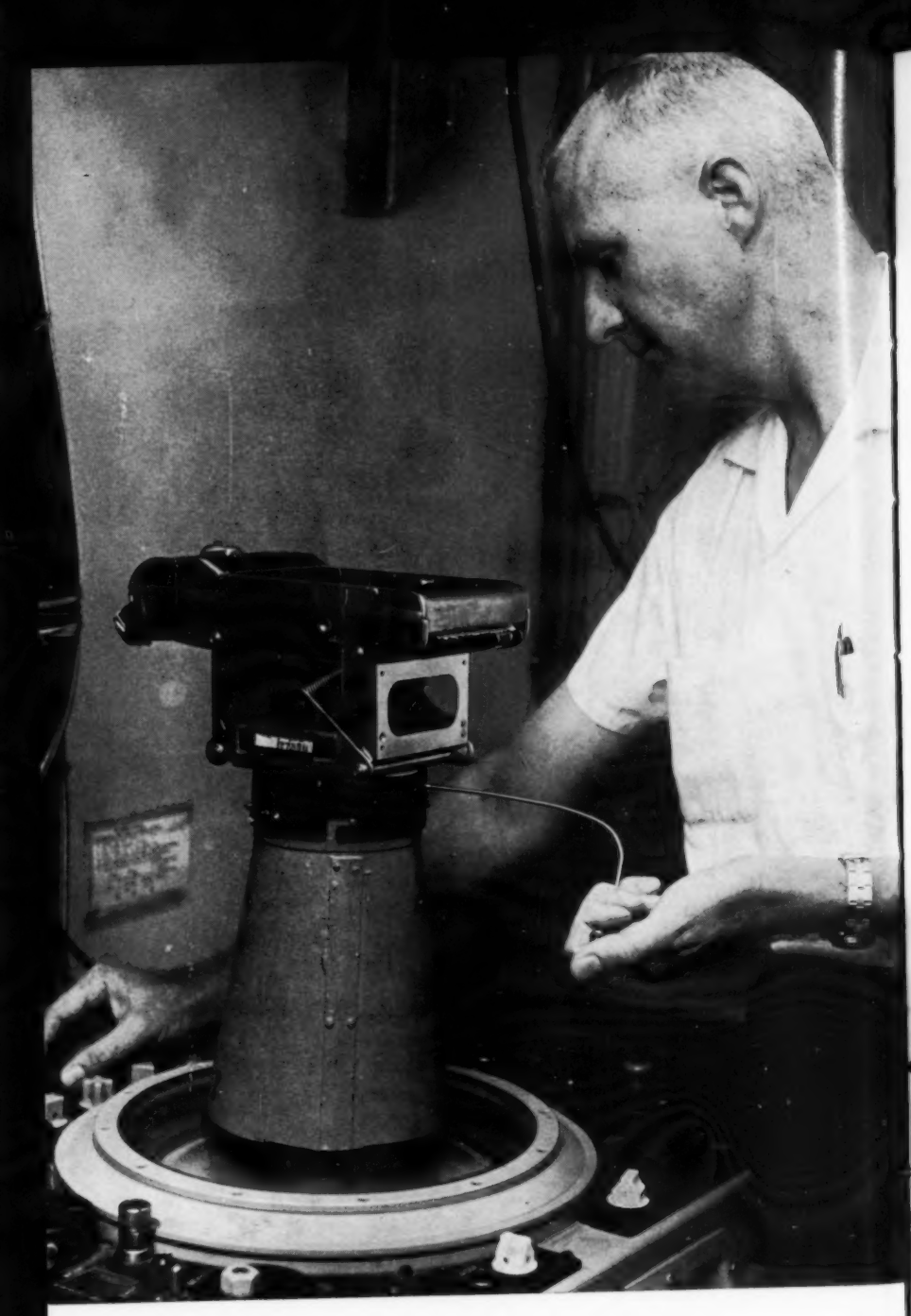
It Seemed Like A Good Idea, But--!

Collecting old automobiles and sinking them on shallow sandy sea bottoms to form artificial reefs seems like a perfectly splendid idea. Reefs, normal or artificial, provide excellent hiding places for small fish, which lure larger fish. Fishermen, to say nothing of junk dealers, would profit thereby. But the U.S. Navy takes a dim view of it all.

At any rate, the Navy has informed Miami's Metropolitan Commission that the proposal to form such a reef, near the Miami harbor entrance, was highly undesirable because it would also offer submarines — not ours — a good place to hide. Even the best underwater detection devices could not distinguish clearly between metal junked autos and metal submarines close to the reef.

Specifically, the Navy objects because the proposed reef would not only create a false positive submarine target, but would also prevent effective mine-laying, minesweeping and mine-hunting operations.

A similar artificial reef near Jacksonville is not considered objectionable by the Defense Department because its location is only 72 feet deep, compared to 100 feet or more at the proposed site, two and half miles off the entrance to Miami's busy harbor.



What We Need To Know About Hurricanes

By HOMER W. HISER AND HARRY V. SENN

Radar Meteorological Laboratory, The Marine Laboratory, University of Miami

EDITOR'S NOTE: Hurricane Donna was the most destructive storm, in terms of property damage, ever to hit Florida, yet the loss of human lives was the lowest in the history of major tropical storms. Much of the credit for this fine record is due to the precautions taken by the State's residents themselves. Kudos go also to meteorologists and other scientists who properly diagnosed Donna as a hurricane of the first magnitude, accurately plotted the course of the storm's center, or eye, and issued forecasts sufficiently far in advance so that people had ample time to board up and take shelter. The authors here give a behind-the-scenes report of their activities at The Marine Laboratory preceding, during and after the passage of Donna, September 9-10, 1960, plus some comments as to what science is doing or should do about hurricane research before another "season" comes around.

IN THE PACIFIC they are called Typhoons; in the Indian Ocean, Cyclones; in the Philippines, Baguios; and in Australia, Willy-willies. But in the North Atlantic Ocean, Caribbean Sea, and Gulf of Mexico, the dread word that signals the atmosphere and sea are on the rampage is: "Hurricane."

Hurricanes form near, but not on the Equator, and always over water. For it is release of energy stored in water vapor, derived by evaporation when air passes over vast reaches of warm ocean waters, that triggers these fearful "heat engines."

BUSIEST MAN *during a hurricane is a meteorologist recording radarscope photographs of its course. Homer W. Hiser uses a polaroid camera to trace Donna's progress. These pictures constitute invaluable source material, which may some day help to unlock such mysteries as what causes a hurricane to release such vast amounts of energy, and why these great storms so suddenly change their directions. (University of Miami)*

"Favorable" Conditions

While no sure-fire method of predicting or pin-pointing the birth of hurricanes has yet been devised, meteorologists know that such tropical storms almost always form in pre-existing weather disturbances, such as old frontal systems or easterly waves. But, although weather forecasters can spot conditions which may be "favorable for hurricane development," they are not able to warn definitely of an impending storm until after a "circulation" is actually observed.

What is the genesis of a hurricane? Meteorologists, still lacking many essential facts, are loath to be too precise. Generally speaking, a tropical low-pressure area is the first ingredient, although not all low-pressure areas develop into hurricanes. But,

TOPSIDE VIEW *of the "eye" of Gracie, a 1959 hurricane. Research flights indicate that much of a hurricane's tremendous energy is released within a few miles of the storm's calm eye. In a single second such storms discharge more power than several atomic bombs; or, to put it another way, a hurricane expends more total energy than fifty years' production of electricity in the United States. (U.S. Navy)*

in a few cases, for reasons still mysterious, a low-pressure area may rapidly draw in winds from all sides, and the rotation of the earth gives them (in the northern hemisphere) a counter-clockwise spinning movement, or "circulation." First warnings usually come from a ship or plane at sea, or perhaps an island observatory.

The counter-clockwise circulation of a hurricane may at first appear as weak and as relatively innocent as other major air movements. But, after a few days, the disturbed area builds up much higher winds and stormy weather, spiraling inward at low levels to a "central eye." Instead of filling up with air, however, the eye becomes a region of lowest air pressure, because air is leaving the storm at higher levels in the atmosphere faster than it flows in at the lower levels. A kind of weather chain-reaction continues the build-up.

Hurricanes which are destined to become "great" spend the next few

days intensifying until winds reach speeds greater than 150 miles per hour, and the central pressure drops below 28 inches of mercury on the barometer.

Wave Tops Torn Away!

When this happens, the sea and the lowest levels of the atmosphere almost become one. Waves reach incredible heights until the winds become strong enough to tear away the wave tops! The ocean-air boundary then is an indistinct mass of boiling, streaked white foam. Photographs from reconnaissance planes during the height of a hurricane must be taken some distance above the normal surface of the sea, which has been described by observers as a conglomeration of waves, foam and flying spray which limits all visibility to a few feet.

In recent years impressive ad-

SEA FURY! *This is how the surface of the ocean appears as it is being lashed by eighty mile an hour winds during a hurricane. When wind velocity rises to more than 150 miles per hour, as it did during Donna, the sea and lowest levels of the atmosphere become an indistinct mass of boiling, white foam, with waves reaching such heights that the wind tears away their tops. (U. S. Navy)*

vances have been made in tracking hurricanes at sea — extremely valuable work because it provides the data needed to give ample advance warnings to land areas and shipping in their paths ("Tracking Hurricanes at Sea," SEA FRONTIERS, May, 1958, Vol. 4, No. 2). Earth satellites carrying cameras have also photographed hurricanes from hundreds of miles above, even discovering a Pacific typhoon, the existence of which was generally unknown prior to the taking of the photograph. A striking picture of clouds swirling into the eye of hurricane Gracie, 1959, was snapped by a U.S. Navy reconnaissance aircraft as it circled in the relative calm above the eye.

Research Coordinated

Research, too, has at long last been coordinated. Most of it is now conducted or organized by the National Hurricane Research Project of the U.S. Weather Bureau. The Radar Meteorological Section of the University of Miami's Marine Laboratory has actively participated in this research, under contracts with the Weather Bureau, and has gathered much useful radar data on hurricanes under additional sponsorship of the U.S. Navy Bureau of Weapons.

In the past, weather-theory has been impeded because of the scarcity of information about the ocean areas where hurricanes are born and develop in their "natural habitat." Recently, however, great quantities of such information have been gathered by reconnaissance aircraft, land-based and airborne radars, and more and better instruments at both shore stations and aboard ships.

Continuous Data Needed

Data and photographs obtained from these sources have provided excellent new descriptions of hurricanes for short periods, but, except for filmed radar readings, it has not been possible to obtain data continuously enough to explain how and why changes in hurricane size, intensity and course take place. As many as three aircraft have circled at different levels within a single hurricane at a time, but no good surface network of stations has recorded weather information simultaneously.

When a big storm moves over land, although the surface network is operating, aircraft in the area are grounded and can provide no information. Also, the planes and crews which observe the storm while at sea are generally worn out by the time the storm reaches land. Of course, the structure of the hurricane also changes as it moves inland. Surface friction increases and winds decrease; the direct energy source, the ocean, may be many miles away. Changes in the storm are difficult to measure because of the lack of continuous soundings at various levels.

Radar's Contribution

One bright spot has been radar information. Since radar sees through darkness, cloud and rain for as much as 200 miles, information is almost continuous. A series of photographs of recent hurricane Donna reveals how rain patterns look on the radar-

scope, as they reflect radio signals back to the radar.

The Radar Meteorological Station of Miami's Marine Laboratory operated two radars and tracked hurricane Donna for about forty hours as she approached and raged through the Keys, and south and central Florida. One of the early eye positions, 159 miles southeast of Miami, was obtained at 8:00 a.m. eastern standard time, on September 9. Actually the outermost rain squalls from Donna were detected much earlier, at about 4:30 p.m. on the 8th, but the eye did not become visible on the radars until early on the 9th.

PATH OF HURRICANE DONNA, *September 9-10, 1960. Florida's most destructive storm (in terms of property damage) roared in from the sea just south of Miami, skirted the lower west coast, and cut a swath of destruction through the center of the state before heading north to die in Canada's maritime provinces. The open dots, bearing initials, are weather reporting stations of the U.S. Weather Bureau network. These also bear an international call number, such as those shown in Cuba and the Bahamas. (Map from authors)*

Accurate Estimate of Course

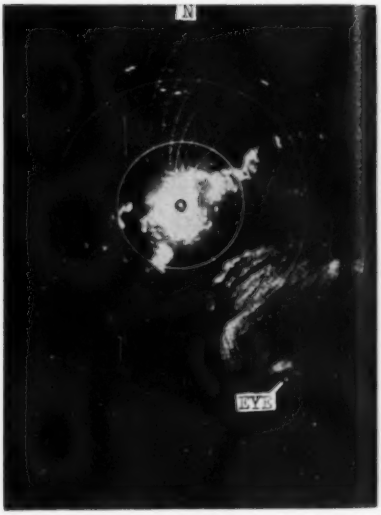
By noon on the 9th, much of Donna was visible on the radars as she was centered 135 miles south-southeast of Miami with rain squalls approaching Miami. At 5 p.m. Donna was centered near Damas Cays, 123 miles south southeast of Miami, and heavy squalls were occurring at Miami. Radar energy is reflected from raindrops within the storm, and the white swirling spiral structure is typical of major hurricanes as seen on a radar located within about 150 miles of the storm center.

From the radar data early on the 9th, it was estimated that Donna would pass through the middle Florida Keys. About noon of the 9th, a look at the upper level winds at 30,000 feet led to the conclusion that Donna would traverse the west coast of Florida and remain under the watchful eyes of our radars for many hours. At 11:30 p.m., Donna verified these predictions all too well by heading for Long Key and the southern tip of the Florida peninsula, where sustained winds of 120 to 140 miles per hour occurred. Top velocity in gusts was estimated at 180 miles per hour.

Emergency Power Used

After many short intermittent power interruptions, commercial power finally failed on the University campus at 10:30 p.m. of the 9th. Operations on the SP-1M, the most powerful of our two radars, were sustained by use of an emergency engine generator. At 4:40 a.m. on the 10th, it became necessary to suspend op-

EYE OPENER. *Although Donna's rain squalls were detected on September 8, 1960, the eye did not become visible on the Miami Marine Laboratory's radar until shortly before 8 A.M. (EST) on the 9th, 159 miles southeast of Miami. Each big white circle delineates a 50-mile band. The tiny black circle (center) marks the location of the radar station. (Photograph from authors)*



DONNA THREATENS MIAMI. *At 5 P.M. (EST), September 9, 1960, the huge mass of the hurricane turned more to the northwest, and heavy rains began to pummel the famous "Gold Coast," which feverishly continued its last-minute boarding up. This is how the storm looked as it passed near Damas Cays, 123 miles south-southeast of Miami. (Photograph from authors)*

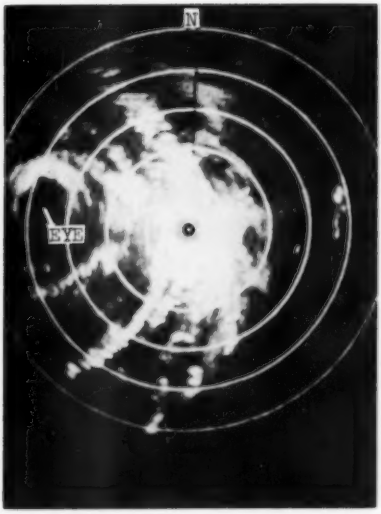
erations because high winds would no longer permit rotation of the exposed antennas. If the antennas had been covered by a plastic dome, operations could have been continued throughout the hurricane.

Shortly after 10 a.m., on the 10th, operations were resumed when wind gusts decreased to approximately sixty miles per hour, again permitting the rotation of the antennas. At this time Donna was seventy-five miles west-northwest of Miami and approaching Naples, on Florida's Gulf coast. By 7:30 p.m. Donna had started to move into central Florida, and was centered about 140 miles northwest of Miami, between Sebring and Bradenton.

Best Documented Storm

Radar tracking continued until the late afternoon of the 10th, and a total of 800 feet of 35-mm radarscope film was collected on Donna by the University of Miami alone. Other radars from San Juan, P.R., to New England obtained additional film records of this hurricane as it passed within range, greatly enhancing the wealth of data which have been collected

WHEN THE GREAT STORM'S *center was only seventy-two miles from Miami, the radarscope revealed this strange formation, shaped like a prehistoric monster. Donna's ominously winking eye is the ox-bow to the south. The white area in the middle of the picture indicates torrential rains falling around the radar apparatus on the main campus of the University of Miami. The time: 11:30 P.M. (EST), September 9, 1960. (Photograph from authors)*



OBSERVATIONS RESUMED. *From 4:40 A.M. (EST) to about 10 A.M., September 10, it was necessary to suspend radar operations because the high winds would no longer permit rotation of the exposed antennas. Here Donna's eye (left) is nearing Naples, on the Florida West Coast. Each large circle encompasses a band twenty miles wide, extending out from the black-circled dot representing Miami. (Photograph from Authors)*

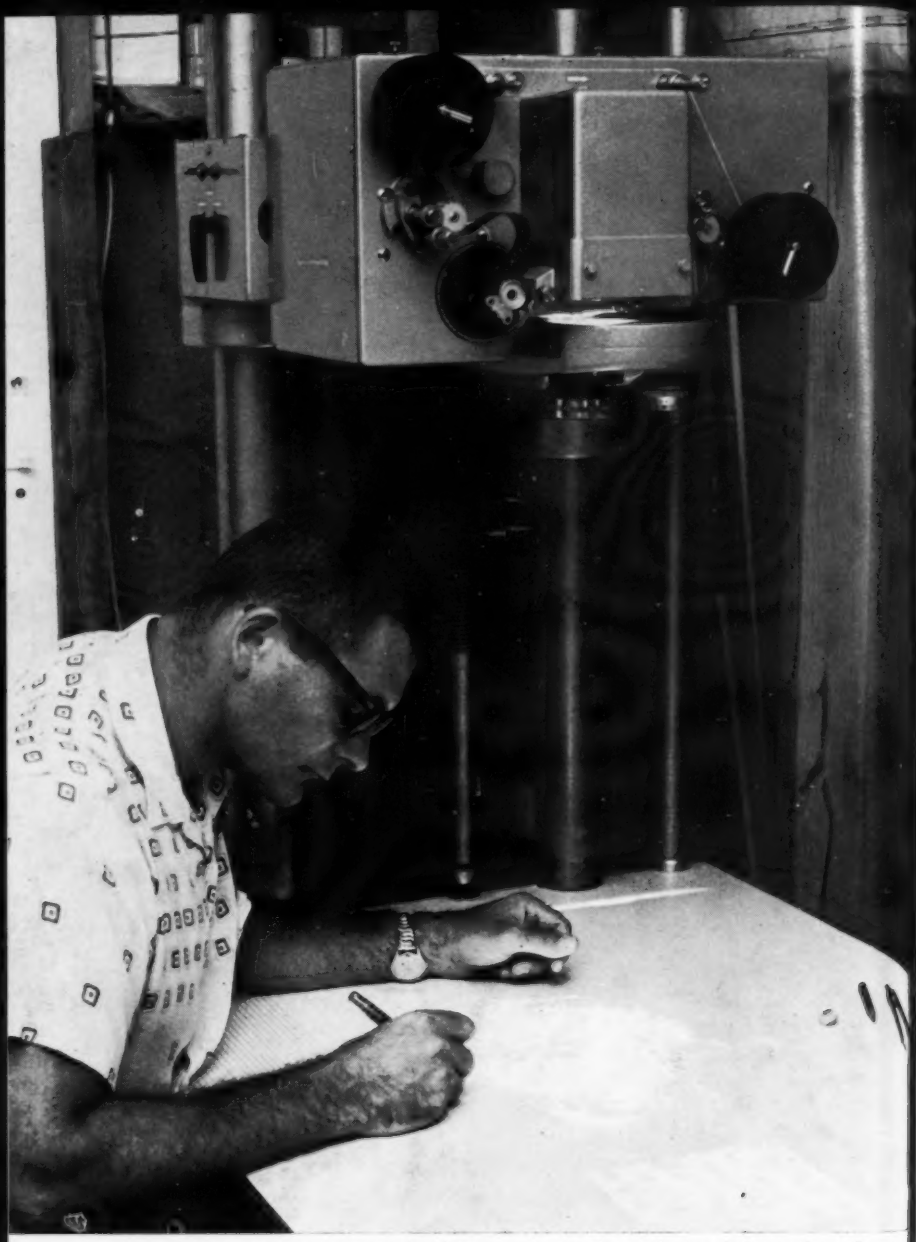
since World War II. Researchers will spend many months analyzing the records from Donna, the best documented storm in history.

As a result of original research at the University of Miami's Radar Meteorology Laboratory, a system of transparent plastic spiral overlays has been developed for placing over the radarscope. These overlays match the inward spiralling weather, shown "live" on the radarscope, and thereby aid in locating the storm center at those times when only a portion of the storm is visible on the radar.

Also, much valuable scientific information has been secured about the internal structure and movement of rain elements in the hurricane circulation. After viewing radarscope photographs of many hurricanes, a "radar model" of a hurricane was developed, and Donna closely approximates this model.

Storm Sleuthing from Rockets

Other weather research, now in progress, concerns the thermal, pressure and wind fields of hurricanes,



AFTER THE BIG WINDS GO, *scientists spend months analyzing information about them, gathered on film. Here co-author Harry V. Senn uses a Nemeth Radar Data Plotter to study Hurricane Donna, and the weather elements surrounding it. Film from a projector (overhead) can be run later as a continuous motion picture, or halted for notations of information. (University of Miami)*

both at the earth's surface and aloft. The U.S. Weather Bureau and the U.S. Navy are cooperating in attempts to photograph hurricanes from high-altitude rockets. An automatic weather station now rides at anchor in the Gulf of Mexico, and radios the air and ocean temperatures, pressure, humidity, and wind direction and speed to coastal listening posts every few hours. Satellites, with better cameras and ground programs to use the information more rapidly, are being readied for the coming year.

Looking to the Future

Although much has been and is being learned about these vicious storms through continuous year 'round studies, meteorologists are finding it necessary to team up with oceanographers, instrument specialists, physicists, and space technologists in an attempt simply to describe the "animal" adequately. With an adequate description of hurricanes, we should quickly break through the barriers which remain in the way of accurate forecasting of hurricane formation and movement. Even when this is achieved, the ultimate problem of hurricane modification: taming and steering the great storms, will remain to be solved.

What do we need in order to accomplish the above? We could reply: More instrumented aircraft. More radars. More rockets. More satellites. More remote automatic radio surface weather stations at sea. More personnel to analyze the data. More, in fact, of the basic research tools which most sciences urgently need. Meteorological knowledge has lagged behind that of other sciences because much of our research must be done in nature's laboratory, and the cost of observation equipment really mounts up for field operations on such a grand scale.

Dam Plan Old Stuff

A proposal by Soviet scientists to dam Bering Strait, between Siberia and Alaska, as a means of warming the Arctic Ocean is nothing new. Both Soviet and United States scientists have discussed it for a number of years, and the general feeling among American oceanographers is that the effect would be to chill further, rather than warm, the Arctic Ocean north of Alaska and Siberia.

However, the blocking of the Strait might warm the Bering Sea to such an extent that some frigidity would be taken from both eastern Siberia and western Alaska. It is believed that the Arctic climate might be affected, should the dam be built, by having giant pumps lift great quantities of warmer Bering Sea water over the dam and dump it into the Arctic Ocean, admittedly a very costly procedure. However, should tides permit, a gate might be installed in the dam which would permit water to move only in one direction.

SEA BOTTOM CLOSE-UP. *This unusual photograph, taken at a depth of about 1,800 feet off the California coast, resembles a softened lunar landscape. The fuzzy white balls are sea urchins, and the low mounds indicate where large worms have thrown out waste materials and mud. Other animals lie concealed in the ooze. (University of Southern California)*

Pollution in the Open Sea

By J. LAURENS BARNARD
Allan Hancock Foundation
University of Southern California

AQUATIC POLLUTION has been a field of scientific study for more than six decades, but only recently has it been extended to include pollution in the open sea. Highly industrialized countries such as the United States and those of Western Europe have been confronted with pollution blights in rivers and estuaries to the extent that water uses were curtailed and fishery resources were damaged or destroyed. Now, the disposal of waste in the open ocean has reached such an extent in some maritime localities that concern is felt over the potential damage to recreational and commercial uses of open-ocean waters.

This concern is felt especially in large coastal cities, which lack rivers where waste can be diluted and flushed into the sea or where waste is disposed into the confined waters of partially landlocked bays. Examples

are Los Angeles and San Diego, in arid southern California, and Miami, Florida, located on Biscayne Bay.

Bathing Beaches Closed

This article is concerned primarily with problems in southern California, where flushing rivers are absent and where large volumes of industrial and treated domestic sewage are emptied directly into the open sea. The problem at Los Angeles reached such an extent in 1943 that several miles of bathing beaches were closed periodically until 1951 because of high bacterial counts in the surf zone. Then a new disposal plant was opened at Hyperion and restrictions were lifted from the beach. A program for future prevention of this problem was developed, but the staggering population increase in the Los Angeles area may mean a recurrence of inshore pollutional conditions.

Recently a new sludge outfall was opened, extending seven miles into the ocean to a depth of 300 feet. A second outfall, five miles in length, is being built for liquid effluent. Part of the basic research necessary for the engineering of these installations was done at the Allan Hancock Foundation, using the research vessel *Velero IV*.

Two Critical Problems

Two of the critical problems were, first, the kind of bottom sediment providing support for the outfall pipe, and, second, the rate of disappearance of coliform bacteria in sea water. Answers to these needs required a pipe seven miles long, emptying into deep cool water, so that waste would not float to the ocean surface and then be washed onto the beaches.

Potential pollution problems in southern California are of such magnitude that the State of California Water Pollution Control Board initiated a five-year research study through the Allan Hancock Foundation in 1956. This survey was undertaken by a research team of twelve scientists, studying 250 miles of coastal shelf, from the intertidal zone down to depths of 300 feet. The farsightedness of the State of California was evident in their supporting a basic program designed to discover the properties and seasonal fluctuations of inshore water masses, the kinds, numbers and distribution of animals and plants in the water and on the sea bottom, and the kinds and distribution of sediments on the bottom.

Engineers Need Oceanic Data

In designing new sewage installations, engineers require detailed information on the direction and speed of ocean currents in order to assess the rate at which the waste will be diluted and dispersed. They must know the fluctuations in the depth of the thermocline, which is the water depth where the temperature changes quickly from warm to cool. Just as atmospheric pollutants are held down by a thermocline in air, so ocean wastes can be held at depth by the thermocline and dispersed without floating to the surface.

Engineers need to know also the sea water temperature at the bottom, so that they can predict the cooling effect the water has on the outfall pipe and its waste. The waste must be

THE STERN WORKING DECK *of the* Velero IV *shows the orange-peel grab, which obtains bottom samples. Disposal of city wastes in the oceans has reached such proportions that grave concern is felt over the potential damage to fisheries and bathing resorts. This is especially true near large coastal communities lacking rivers where waste can be diluted and flushed out to sea. (University of Southern California)*

cooled to a temperature below that above the thermocline so that it will not float to the surface. Thus, the longer the pipe, the more time for cooling of the waste.

Mysteries of Inshore Currents

Scientific ignorance regarding the sea is no better demonstrated than in southern California. Physical oceanographers and geologists call the southern California coast the best known large sea area in the world. It has been thoroughly mapped; a great deal of marine geology has been done; and hydrographic stations have been occupied monthly for more than two decades. Yet, we know little of the inshore currents and their seasonal changes, which is important knowledge to engineers building new disposal plants.

The Hancock Foundation has been studying the movements of water using drifting objects and dye and relating this to local wind conditions. It was shown that tides produce very little of the inshore current action, but local winds cause the major changes in direction and velocity of currents. Thus, it became possible to explain and predict the dilution rate of waste discharge.

Little is recorded, also, of the nor-

mal turbidity of sea water. In court hearings, witnesses testified that pollution was clouding the whole coastal water mass and that "grandfather" used to tell of seeing the ocean bottom from the ends of piers, but that this was now impossible. Research into this problem showed that "grandfather" indeed saw the ocean bottom from the pier but that his memory of this phenomenon was reinforced by its rarity. The water has always been turbid.

We now know that the rare combination of physical events producing clear water occurs now and in the past at about the same frequency. California coastal waters are naturally very turbid due to high plankton productivity and suspended silt and clay washed from land. For this reason, skin divers find California coastal waters rather disappointing since underwater visibility is poor. Indeed, the waters are so clouded naturally that marine red algae rarely grow below a depth of 120 feet, while in clear seas where light penetrates farther, they grow to depths of 600 feet.

Many New Bottom Animals

Virtually nothing is known about the kinds of bottom animals and how they are organized into communities or about their usefulness as food for commercial and sports fisheries. Thus, we could not assess the potential damage sewer outfalls might cause by destroying life. Research into this problem revealed the amazing fact that more than half of the 2,000 kinds of bottom animals in the region were unknown to science!

Of those which had been previously found, nothing was recorded of their distribution — why they live where they do. By collecting more than 1,000 quantitative samples of bottom life those working on the project were able to map either broad bands or patches of community organization and relate these to physical conditions. Thus, it was disclosed that sandy bottoms are poor in large and weighty organisms (poor in biomass) while fine silts are rich in large burrowing animals.

Silt at 100-foot Depth

But where sandy bottoms are near domestic outfalls, the biomass becomes greatly increased by the growth of filter feeding organisms, which utilize the waste organic materials as food. Normally, fine-grained silts are on deep bottoms, greater than 300 feet, but on the Santa Barbara shelf (Fig. 4) a large bed of thick silt lies in depths of about 100 feet, where the

SHAKER APPARATUS, *with overhead sea water showers, washes out mud and sand but preserves animals and plants for study in the ship's laboratory. Pollution studies of the bottom communities along the California coast revealed that more than half of the 2,000 kinds of bottom animals residing in the region were previously unknown to science. (University of Southern California)*

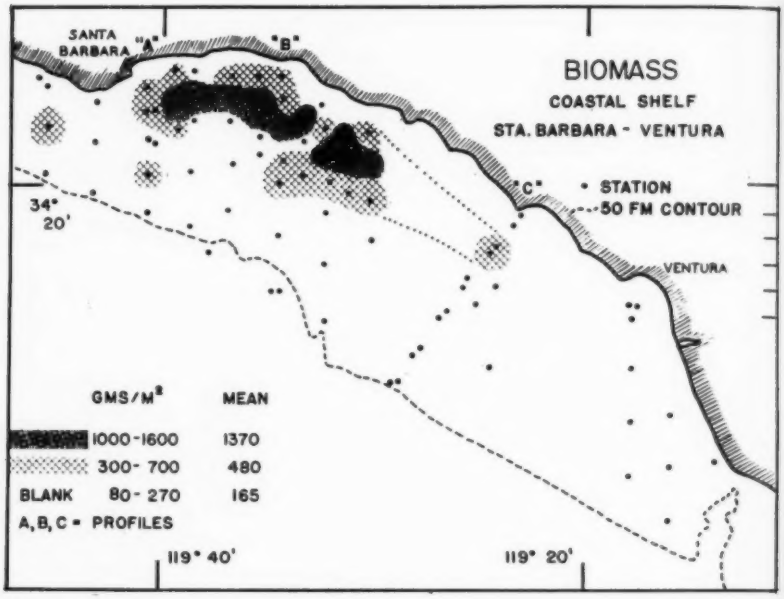


CHART OF THE COASTAL SHELF *between Santa Barbara and Ventura, California, chief operational area of the bottom pollution surveys of the* Velero IV. *Heaviest biomasses (large and weighty organisms) occur in the fine-grained silt beds lying close to the shore; sandy areas and regions far offshore are low in biomass. (University of Southern California)*

better natural food supplies produce very dense bottom faunas.

Each of the bottom communities is dominated by one or two kinds of animals which make up a large share of the biomass. In some cases these species are a clam or a brittle star, in other cases spoon worms, but most sediments are dominated by certain species of polychaete worms. Each kind of community and its dominant species is determined by a combination of the kind of sediment, the food supply, the currents, depth, distance from shore and other factors.

Certain areas of low biomass had been thought to be damaged by domestic pollution, but it was determined that some areas of low biomass normally occur in the sea and in these cases pollution was not to be blamed. This kind of prior knowledge is of immeasurable value to legislators and governmental agencies required to set and regulate criterial standards necessary to conserve the beneficial uses of the sea.

"Red Water" Outbreak

Normal fluctuations in plankton production were virtually unstudied. It was determined that inshore plankton increases in abundance in the vicinity of outfalls, probably due to the

ESPECIALLY CONSTRUCTED AS A RESEARCH VESSEL *for work on coastal shelves and offshore basins,* Velero IV *has operated on many scientific expeditions along the Pacific coast. In addition to the latest navigational aids, this trim 105-foot ship, belonging to the University of Southern California, has three laboratories, several deep-sea corers, bottom grabs of up to six cubic-feet capacity, and various electronic apparatus. (University of Southern California)*

normal discharge of nutrients favoring the growth of the plants. However, the dense blooms causing "red water" along the California coast in the spring of 1958 were not caused by outfall discharges, but by a normal cycle of events, poorly known, but being studied by scientists in many laboratories of coastal seas where this event occurs.

The sea is so complex that large-scale statistical correlations of potential and real pollutional damage are useless until normal conditions are studied. An analogy of this is the need to know the normal radioactive background count of the atmosphere before atomic explosions can be detected.

In this way, the California survey was initiated to study the normal physical properties and life of the sea for a future application to applied sciences, such as sanitary engineering, natural resources and fisheries.

Gold Medal Award To Lerner

MICHAEL LERNER, internationally known angler, received the first gold medal award of the International Oceanographic Foundation to the sport fishermen judged to have accomplished most for marine science, at a special dinner held at the Deauville Hotel, Miami Beach, November 16.

The ceremonies were attended by some of the leading figures in the world of business, science, sports fishing, and education, as well as many personal friends of the guest of honor. Principal address of the evening "Science and the Public" was made by Ross Leffler, assistant secretary of the Department of the Interior. Dr. Albert E. Parr, of the American Museum of Natural History and a member of the Board of Governors of the International Game Fish Association, introduced Mr. Lerner.

Founded I.G.F.A. in 1939

Lerner's contributions to marine science have been many and varied. He established the International Game Fish Association in 1939, and was president of that organization from 1943 until July 1 of this year, when William C. Carpenter of Wilmington, Del., and Fort Lauderdale, was elected to the office. Mr. Lerner was awarded the title of Founder-Chairman.

In January, 1941, he was made a member of the Board of Trustees of the American Museum of Natural History.

The University of Miami awarded him an honorary Doctor of Science degree in June, 1952. In 1947, Mr. Lerner established and gave to the American Museum of Natural History the Lerner Marine Laboratory in Bimini, Bahamas.

Expeditions to Far Places

Several marine science expeditions have been financed and headed by Lerner, ranging from the waters off Nova Scotia to Australia and New Zealand, while two separate expeditions were made to Chile and Peru. Mr. and Mrs. Lerner have travelled all over the world visiting marine laboratories and conferring with marine scientists and anglers.

The medal he received will be presented annually by the Foundation to some qualifying angler. Its first presentation was made possible by George Collier, vice president of the International Oceanographic Foundation, and also of the International Game Fish Association. In addition to Collier, the selection committee was comprised of Al Pflueger and John A. Manning, members of the Board of Trustees of the Foundation, and Erl Roman, also a member of the board and chairman of the Tackle Committee of the I.G.F.A.

The medal was presented by Mr. Charles F. Johnson, retiring President of the Foundation, who has served in this position for five years.

Chairman for the occasion was Mr. John Manning, newly elected President.

Science of the Sea in BOOKS

General Reading

MARINELAND DIVER

JAKE JACOBS as told to SYLVIA JACOBS. Dodd, Mead & Company, New York, 1960. 178 pp. $4.00.

The chief diver at Marineland of the Pacific, famous aquarium, summar' es fifteen years of commercial div off southern California. His car has included gathering *Gelidium,* alga used in the manufacture of ag salvage work, in which the aut says clearing channels of wrecks has brought more gold to divers (in the form of drafts on the U.S. Treasury) than all the sunken treasure ever found; collecting coral and rare shells; abalone diving; and, finally, his experiences at Marineland.

WHALES IN CAPTIVITY *are extremely rare. Here the author of* Marineland Diver, *reviewed on this page, feeds one of the pilot whales he secured and trained for Marineland of the Pacific. (John Meredith)*

The author feels safer in a diving suit among sharks and big turtles than driving his car through heavy traffic. He describes the only two serious accidents to divers at Marineland during five years of operation. In one case an unusually hungry moray eel lunged for food held in the author's hand, missed, and slashed the diver's fingers. In the other a black sea bass, which another diver was trying to capture, rolled over on its captor, puncturing the diver's chest with a dorsal fin ray. The diver recovered.

The book includes many anecdotes about the behavior of Marineland inhabitants, including the antics of a porpoise which learned *that humans can be taught tricks!* An entire chapter is devoted to Bubbles, the trained pilot whale. The author remarks that turtles bite most often, not because they are vicious, but because they are bungling creatures.

In short, this book is written in direct, nontechnical prose; it is interesting, informative recreational reading. J.K.M.

SEA ANGLERS' FISHES OF AUSTRALIA

ARTHUR W. PARROTT. Hodder and Stoughton, Melbourne, 1959. 208 Pages, including Index. 25s. 0d. ($3.50)

Mr. Parrott has given us a most useful little book on the fishes of Australia, little only in its cubic size and consequently of great usefulness as a pocket or tackle-box item. For Australia, it is in a class with Miss Francesca LaMonte's *North American Game Fishes,* and supplements the Australian items in her *Marine Game Fishes of the World.*

It is not comparable as an attractive book with either T. C. Roughley's *The Fish and Fisheries of Australia,* D'Ombrain's *Game Fishing Off the Australian Coast* or Prof. J. L. B. Smith's *The Sea Fishes of South Africa,* and probably not as scholarly as any one of them, but the format and size of of those three admirable works make them difficult for the angler or scientist to use in the field, as witness the battered condition of my copies.

Parrott's format is far more useful to the angler and commercial fisherman and comprehensive enough as a starting point for a field scientist on location. In the same class should be mentioned Coats' *Fishing on the Barrier Reef and Inshore,* for Queensland, and Goadby's very good little pocket book *Sharks and other Predatory Fish of Australia.*

Parrott's relation of the fish of Australia, with their local common names, to those of East Africa and New Zealand with their local common names, is again useful to both the world angler or the scientific student of world distribution of fishes, but again to the latter only as a starting point. Undoubtedly, there are many errors and omissions from a purely scientific point of view. In the particular family of fish, about which I feel competent, the Istiophoridae, I know there are.

For instance, at the very opening of his section on "Swordfishes and Marlins," Parrott places the broadbill swordfish *Xiphias gladius* in the "Histiophorids" (fishes of the family Histiophoridae-Istiophoridae). This is an error; no ichthyologist for many years has placed the broadbill in the family with the marlins, sailfish and spearfish, (the Istiophoridae-Histiophoridae). It belongs in a family of its own, the *Xiphidii,* in which there is only one genus, *Xiphias,* and only one species, *gladius.* This is not only an error in the use of scientific nomenclature, but in classification.

But then, it seems clear from the Preface that the author did not intend this work as a scientific publication and some scientific inaccuracies, in

the reviewer's opinion, do not outweigh its value to the angler and the commercial fisherman of inquiring mind, or even to the field scientist working in a new and foreign field, but in the latter case, as stated above, only as a starting point. J.K.H.

FISHING OFF PUERTO RICO

ESTEBAN A. BIRD. A. S. Barnes Company. New York, 1960. 111 pp. ($3.95)

As the leader of a fishing team successful in international big game fishing tournaments, the author, "Chilo" to his friends, is well qualified to write about fishing off Puerto Rico. He and his friends of the Club Nautico de San Juan are largely responsible for the development of marlin fishing in this area since World War II.

Anglers will like to read of the history of this development and of the personalities who took part in it. They will be particularly happy to note that detailed accounts of fishing methods and local knowledge of fishing conditions are given for the benefit of visiting anglers. The biologist will be agreeably surprised to read the author's observations on the relation of catches to ocean currents, temperatures, and seasons. Above all, neither angler nor biologist will find here the exaggerations and sports writers' prose that spoil so many books on big game fishing. F.G.W.S.

Technical Reading

THE FAUNAL CONNECTIONS BETWEEN EUROPE AND NORTH AMERICA

CARL H. LINDROTH. John Wiley & Sons. New York and Almqvist and Wiksell, Stockholm. 1957. 344 pp. and 61 illustrations. $15.00.

Although this book is not directly concerned with either marine life or the sea, it cannot be overlooked by anyone interested in zoogeography or the distribution of animals. The author, Carl Lindroth, is the authority on the carabid beetles of Europe and northern North America. For many years he has been interested in the occurrence of similar species and, in some cases, of identical species of beetles inhabiting eastern Canada, on the one hand, and western Europe on the other. This book summarizes his findings on the beetles, birds, and plants of the two areas and explains their relationships.

The marine zoogeographer will find a wealth of information in this book on the possible means of migration of shore animals and plants from western Europe to America, which will aid in explaining similar distributions of intertidal and shallow water marine animals and plants. A fascinating study by Lindroth is the introduction of animals and plants from southwest England in ballast carried by sailing ships to Nova Scotia, where the ships took on salt fish for the homeward voyage. The unravelling of this problem by the author reads like detective fiction, and is an important bit of maritime history.

Means of dispersal other than by man also are given. Dispersal from west to east by the Gulf Stream is discussed and there is an excellent section on the possibilities of former land connections from Europe by way of the Faroes, Iceland and Greenland.

Wegener's continental drift theory is mentioned but this reviewer agrees with the author that continental drift, if any, would have taken place so early in geologic history that the distribution of our present species would not have been effected by it. This book is recommended to all professional biologists interested in animal distribution. G.L.V.

About the Authors

J. LAURENS BARNARD

Essentially the work Dr. Barnard is doing is a census of the sea-bottom — a statistical measurement of animal distribution, biomass, communities, and a combination of zoology and geography that might be termed zoogeography. While working for the Allan Hancock Foundation, University of Southern California, he also is cooperating with the Lamont Geological Observatory in a special study of deep sea organisms, especially amphipods.

In 1960, Dr. Barnard will join the new Beaudette Foundation at Solvang, California, commencing a long term research program on bays, lagoons, and estuaries in the Gulf of California and the west coast of Lower California. A native of California, and a graduate of the University of Southern California (A.B., M.S., and Ph.D.), he spent a year as an instructor at the California State Polytechnic College before returning to his first love, the study of marine organisms.

Dr. Barnard lists his hobbies as travel (his wife and three children take a long trip every other year) and collecting, everything from stamps, coins, and sea shells to photographs of fire trucks taken in California cities over a six-year period.

MARGARET BIGGERSTAFF

Mrs. Biggerstaff's first interest was music, which she studied both in the United States and abroad. In addition to being an accomplished violin soloist, she organized four symphony orchestras, serving as concertmaster of two.

It was script writing on TV, however, that led her into oceanography. For the first NBC show in color, Mrs. Biggerstaff used flowers of the New York Botanical Garden as an exponent of true color. The producer of this show, the Alfred P. Sloan Foundation Series on "The American Inventory," later want-

ed a script on Oceanography, and for several years this science became her hobby. At the International Oceanographic Congress, in New York, in August 1959, she was invited to join the staff of The Marine Laboratory, University of Miami, where she is presently a special assistant to the Director.

ERNEST S. REYNOLDS

Born in a Montana mining camp, where his father was chemist, Dr. Reynolds reversed Greeley's advice by "going east" to Rhode Island, where he attended Brown University (A.B. and A.M.), and later obtained his doctorate at the University of Illinois.

A specialist in plant physiology and plant pathology seems remote from military problems but he received the Naval Ordnance Award for service during World War II "in connection with the research and development of materials, methods and processes for protection against tropical deterioration."

Since 1946, Dr. Reynolds has been research associate professor at the University of Miami, and has been in charge of pioneer studies of salt water

fungi at the Marine Laboratory since this research was started in 1945. He is a Fellow of the American Association for the Advancement of Science, and has contributed to a number of scientific journals. Gardening and photography are his hobbies.

Longest Overseas Flight by Mammal?

Once a bat flew more than 2,000 miles across the Pacific from the west coast of North America to Hawaii! This is described as probably the most remarkable mammalian flight of all time by Dr. David H. Johnson, Smithsonian Institution curator of mammals, in a report on the present-day mammals of the Pacific islands of the Pacific Ocean.

The animal was the hoary bat, a fairly common species in western North America. It is, unlike most kinds of bats, a solitary creature which roosts in trees and in winter migrates, instead of congregating in caves. It has probably been in Hawaii for thousands of years, arriving before man. During this time it has undergone various changes, but its relationship with the mainland bat is unmistakable.

There is apparently only one way by which the ancestor of the Hawaiian bat could have reached the islands—by just such an epic flight over open water. It was, in all probability, a pregnant female that had lost her way in the northward spring migration.

Congratulations

MEMBERS are to be congratulated that their numbers have more than doubled every twelve months in the few years since the Foundation began its work. They are drawn from the United States, Canada, Central and South America, Great Britain, Australia, France, Germany, Italy, Turkey, Denmark, Sweden and Norway as well as a few from the Pacific Islands, the West Indies and Russia.

CONTINUED IMPROVEMENT will be possible with growth of active membership. It will be seen in better service, with more articles in the magazine of high interest and authenticity and, eventually, a monthly issue in full color.

IN ADDITION TO PUBLISHING *Sea Frontiers* and *Sea Secrets,* the Foundation provides active support for scientific research and education. The ocean is our last frontier and its exploration still under way.

MEMBERS are joined in these aims and they are urged to make progress possible by taking the small effort needed to enlist new members. Sample copies will be mailed to friends upon request.

INVITATION: Those who are not members, but whose interest and curiosity lie in the sea and the spirit of discovery, may participate by simply mailing the card in this issue.

THE EDITOR will be glad to consider for publication articles and illustrations covering explorations, discoveries or advances in our knowledge of the marine sciences or describing the activities of oceanographic laboratories or expeditions in any part of the world.

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"To encourage the extension of human knowledge by scientific study and exploration of the oceans in all their aspects, including the study of game fishes, food fishes, ocean currents, the geology, chemistry, and physics of the sea and the sea floor."

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We urge you to consider membership. An annual membership of $5.00 will defray the cost of printing and mailing of your *Sea Frontiers* and *Sea Secrets*. All other memberships will, of course, provide a measure of support to vital research and scholarships.

According to a ruling of the U.S. Treasury Department, donations made to the Foundation are deductible in computing taxable income as provided for in the 1954 code.

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